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# THE SCIENTIFIC MONTHLY

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# LATELY PUBLISHT

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THE SCIENTIFIC MONTHLY

NOVEMBER, 1916

# EXPLOSION CRATERS

By N. H. DARTON

U. S. GEOLOGICAL SURVEY[1]

ALTHOUGH most great craters are on top of volcanic peaks, a few big holes of volcanic origin are on plains and not connected with lava outflows. These are rimmed by a ridge of fragmental material evidently blown out of the hole, so that they are clearly the results of an explosion. One crater of this character, however, Crater Mound (formerly Coon Butte) in Arizona, is believed by some observers to have been caused by impact of a meteor. As there is no direct evidence as to the origin of this great hole and its rim of fragmental ejecta, it may be interesting to present for comparison facts regarding some craters which are closely similar in all essential respects.

Among long-known holes ascribed to volcanic explosion and not connected with lava outbursts are the "maars" in the Rhine valley and the craters of Eiffel, Auverne, Montecchio, Albani, Nemi, Astromi, Faifa, etc., of Nassibe, in Madagascar and at Lonar, India. The latter, as described by Dr. Blandford, is a hole about a mile in diameter, 300 to 400 feet deep, in a great lava plain. Except on the north and northeast sides, there is a rim 40 to 100 feet high composed of loose blocks of basalt similar to the rocks on the sides of the hole. The latter are bent up very slightly. As to the competency of volcanic explosion to cause a crater, many illustrations have been observed, notably in the great Bandai-San eruption[2] in Japan in 1888, which made a vast crater in a mountain where there had been no activity for many centuries. There was no lava effusion connected with this outburst. The eruption of Krakatoa in 1883 is another impressive instance.

In the course of the present European war many a huge "crater" or "entonnoir" has resulted from the explosion of "mines" intended to destroy fortifications or dislodge troops, and it is interesting to have an example of this kind to compare with some natural craters. One

[1] Published by permission of the Director.

[2] "The Eruption of Bandai-San," Seis. Soc. Japan, Vol. 12, pp. 139–222, 1890.

large "entonnoir" on the Franco-German line of struggle is shown on Page 429. Judging from some details of remains of passageways shown in the foreground, its diameter is about 150 feet and depth 50 feet. It was produced by the explosion of several tons of some powerful explosive placed in a chamber at the end of a long tunnel 50 to 60 feet below the surface. The end of the tunnel next the chamber was securely blocked before exploding the mine in order to have the utmost

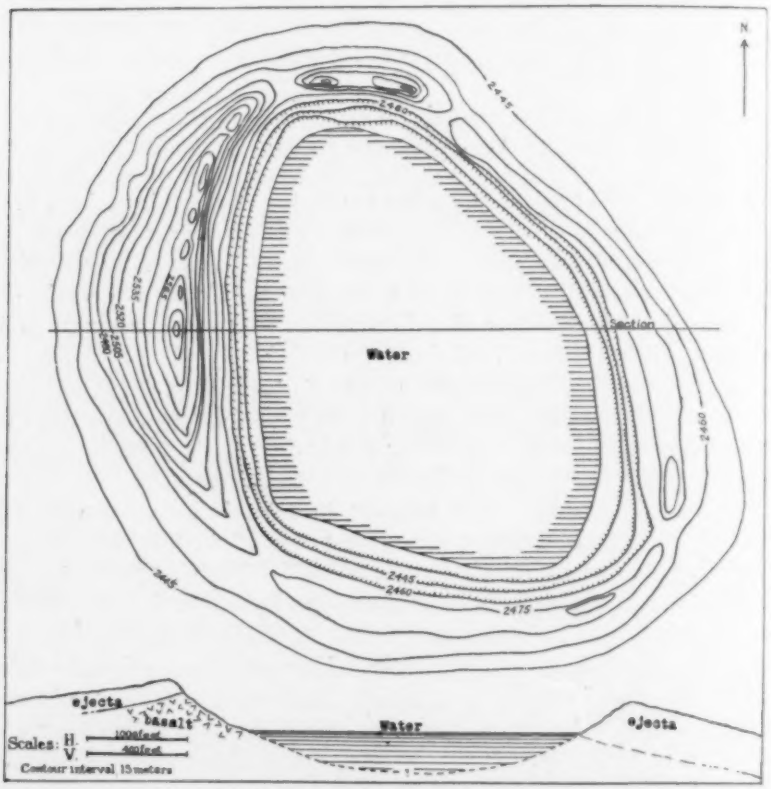


FIG. 1. CONTOUR MAP AND CROSS SECTION OF THE CRATER OF ALCHICHICA IN PUEBLA, MEXICO, AFTER ORDONEZ.

effect of upheaval. The material apparently is compact earth and probably the uplifted material was torn out without much upbending of the sides from which it is detached.

Several years ago Ordoñez described some remarkable craters in Mexico which afford some very interesting facts for comparison. One group is on the plateau near Orizaba Peak in Puebla; the other group is in Valle Santiago. Ordoñez regards them as the result of explosions marking the last phase of volcanic activity in the region. The cause was igneous action at no great depth and the locus of explosion was determined by some superficial influence.

The craters of the Puebla[3] region are in two principal groups. One group of four is in the vicinity of the Hacienda and Sierra of Techachalco, about 25 miles north-northwest of Orizaba Peak and not far southwest of Limon Station on the Interoceanic Railroad. The other group is near Alxoxuca, a small settlement eighteen miles northwest of Orizaba Peak. The configuration and structure of two of the principal members of the first group are shown in Figs. 1 and 2, copied

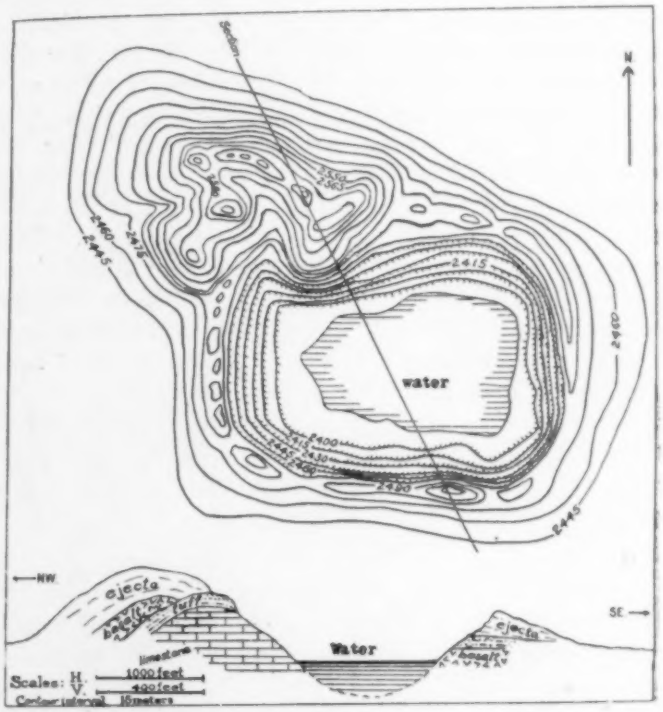


FIG. 2. CONTOUR MAP AND CROSS SECTION OF THE CRATER OF ATEXCAQUI IN PUEBLA, MEXICO, AFTER ORDONEZ.

from Ordoñez's memoir. The largest crater, known as Alchichica, is circular, contains a large shallow lake, and has a diameter of slightly more than a mile. The water level is about 50 feet below the surrounding plain. On the east and south sides the encircling ridge is low, but on the west it rises 325 feet. The inner slopes are steep, the outer ones more gradual. Both walls consist of ash, lapilli and pumice, evidently ejected from the crater, but on the west side these are seen to lie on a mound of basalt of some old flow. Fragments of basalt and of slates, limestones and other materials are included in the mass of

[3] "Los Xalapazcos del Estado de Puebla," Inst. Geol. de Mexico, Parergones, Vol. 1, No. 9, 1905.

ejecta constituting the encircling ridge. There is no evidence of disturbance of the beds.

Atexcaqui, six miles southwest of Alchichica, has an elliptical crater about three fifths of a mile wide from east to west and two fifths of a mile wide from north to south. Some of its features are shown in Fig. 2. The surface of the lake occupying the crater is about 90 feet below the adjoining plain. The encircling ridge is from 200 to 250 feet above the lake, but on the northwest side its height increases to about 600 feet on account of the presence of a mound of horizontal Cretaceous strata on which the ejecta is piled. On the other sides are low walls of basalt, capped by nearly horizontal beds of yellow, andesitic tuff which constitutes the surface of the adjoining plains. The material ejected from the hole and constituting the encircling ridge is piled up on this tuff to a thickness of 40 to 60 feet. The inner slopes of the crater are steep at most places. The ejecta of the encircling ridge is in irregular sheets sloping outward at a low angle. The principal materials are those which underlie the plain: ash, cinders, tuff, and numerous fragments of the basalt. There is also a small proportion of limestone, granite, diorite and andesite, such as probably underlie the locality at considerable depth. The limestone is of the same sort as that which constitutes the hill on the northwest side of the crater. The explosion has blown a round hole through the basalt, limestone and overlying tuff, but has not disturbed the remaining edges. The volume of ejected material is not estimated, but it must be great and apparently sufficient to fill the hole.

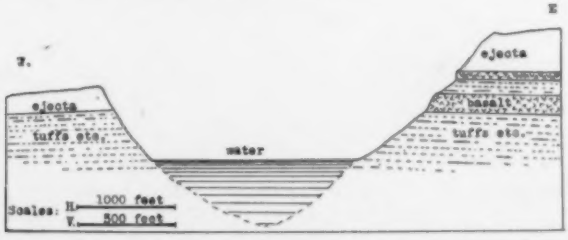


FIG. 3. SECTION ACROSS THE EXPLOSION CRATER OF ALXOXUCA IN PUEBLA, MEXICO, AFTER ORDONEZ.

La Preciosa, a smaller crater with lower surrounding ridge, also contains a lake said to be 275 feet deep. Its rim consists of a mass of ejected material somewhat irregularly distributed. The hole is in the tuff of the plain. Quecholac, which lies out on the plain some distance from the others, is about three fifths of a mile in diameter, with low encircling ridge 80 to 160 feet high. This ridge consists of ejecta, mainly cinders, lapilli and pumice, and a few rocks of the older formations in irregular sheets dipping gently outward. The underlying strata are not exposed. The lake is 300 feet deep.

The craters about Alxoxuca are on the plain at the foot of a volcanic ridge, but the materials in the walls and slopes are entirely of the tuffs which make up the plain. The craters are close to cones from which lava flowed recently, at one place overlapping the ejecta from the explosion craters. The principal crater, known as Alxoxuca, is somewhat more than a half mile in diameter, and the lake which it contains is 200 feet deep. The cross section, Fig. 3, shows the principal features on a west to east line. Two lava sheets are intercalated in the tuff on the east side, which rises considerably higher than the west side. The encircling rim consists, as in other craters, of fine ejecta containing many basalt fragments. The deep large crater of Tecuitlapa contains, as shown in Fig. 4, a conical mass of basalt and

FIG. 4. SECTION ACROSS THE EXPLOSION CRATER OF TECUITLAPA IN PUEBLA, MEXICO, AFTER ORDONEZ.

breccia with three small craters, a feature very similar to Zuñi Lake in New Mexico. Steep walls rise from the central lake to the crest of the encircling ridge of ejecta which is 300 feet high and slopes gently to the adjoining plain. The interior cone and its craters are clearly of more recent age than the large crater and undoubtedly represent a final stage of the volcanic activity.

Two other craters, five miles east of Alxoxuca, are known as Xalapazco Grande and Xalapazco Chico. They contain no water. As shown in Fig. 5, they are less than a half mile in diameter, but the

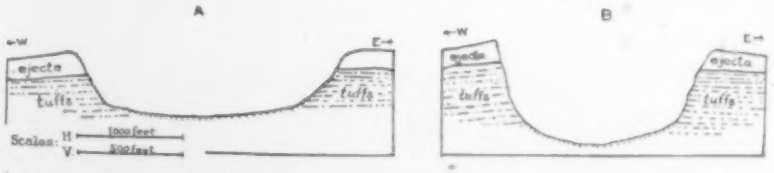


FIG. 5. *A.* SECTION ACROSS THE CRATER, AXALAPAZCO GRANDE. *B.* SECTION ACROSS THE CRATER, AXALAPAZCO CHICO, PUEBLA, MEXICO, AFTER ORDONEZ.

encircling rim does not rise high above the plain. The larger crater is 220 feet deep, and the smaller one nearly 400 feet. As in the case of the others, they are blown out through andesitic tuffs constituting the general valley floor and the rims consist of a large volume of fine ejecta containing much basaltic material. Ordoñez suggests that at the time of eruption a large volume of water was ejected with the

fine materal which would account for the irregular bedding in the ejecta in the encircling ridges.

Other explosion craters in south central Mexico have been described by Ordoñez, notably the fine group of eleven in the Valle de Santiago[4] and the crater at Xico,[5] near Mexico. These craters are in a plain underlain by tuffs and the beds adjoining the holes are not disturbed. The craters are surrounded by ridges of ejecta and all are the products of a similar cause, but in some cases two or more stages of development are apparent. The largest is more than a mile in diameter.

An explosion crater at Tacámbaro, in Michoacán, has been described by Rubio.[6] It contains a lake nearly a half mile in diameter, and the surrounding ridge of ejecta is more than 500 feet high on one side. The walls are basalt and the ejecta are ash, lapilli and tuff, with rock fragments.

Hornaday[7] and Lumholtz[8] have described a group of remarkable explosion craters in the northern part of Sonora, Mexico, fifteen to

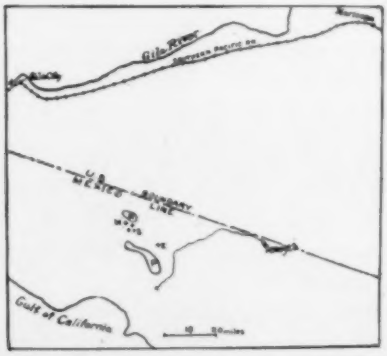


FIG. 6. MAP OF PART OF SONORA DESERT IN MEXICO AND ARIZONA, showing location of craters near Pinacate Mountains, after G. Sykes. *P*, Pinacate Mountains; *H*, Hornaday Mountains; +, craters; *S*, Sykes Crater; *M*, MacDougal Crater; *E*, Crater Elegante.

twenty-five miles south of the International Boundary line, about 100 miles southeast of Yuma, Arizona. This area is shown in the following map:

[4] "Les volcans du valle de Santiago," por E. Ordoñez, Soc. Antonio Alzate Mems., Vol. 14, pp. 299–326, pls. IV.–IX., 1897. Also "Les Crateres d'explosion de Valle de Santiago," por E. Ordoñez, Guide des Excursions Xe Cong. Geol. Int., Mexico, 1906, XIV., Excursion du Nord, 9 pages, plate.

[5] "Los crateros de Xico," *Bol. Soc. Geol. Mexicana*, Tomo 1, pp. 19–24, 1905.

[6] "El Axalapazco de Tacámbaro," por P. O. Rubio, *Bol. Soc. Geol. Mexicana*, Tomo 2, pp. 65–69, 1906.

[7] "Camp Fires on Desert and Lava," by W. T. Hornaday, Scribner's, 1908.

[8] "New Trails in Mexico," by Carl Lumholtz, Scribner's, 1912.

One of these craters in the plain 2½ miles northeast of Tinaja de los Papagos was named Sykes Crater by Hornaday. According to Lumholtz it had been visited by Sr. Y. Bonillas of Nogales in 1882. Sykes, who was geographer of Hornaday's expedition, found that the depth of the crater is 750 feet, its diameter at bottom 1,400 feet, and the bottom is 150 feet above sea level. A view of this great hole is given in Fig. 7. Lumholtz states that the rim is 130 feet high where

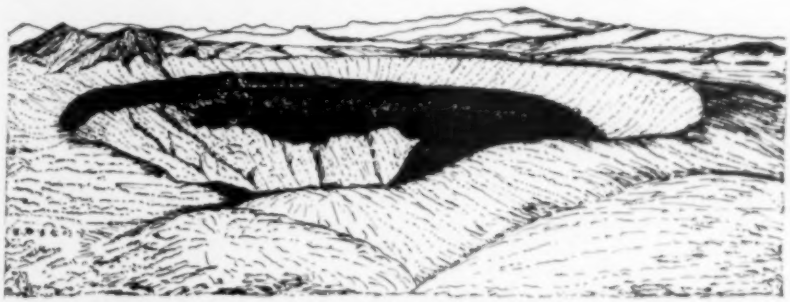

FIG. 7. SYKES CRATER, IN SONORA, MEXICO. Looking southeast. Pinacate Mountains in distance. After a colored view by Hornaday.

he crossed it. It evidently consists of ejecta and Hornaday states that in places the apex of the rim is "sandstone formed by the fusing of masses of volcanic sand under the influence of intense heat" and regards the material as having been thrown out of the crater.

Another great crater in the same vicinity has been named MacDougal Crater by Hornaday. It is in the lava plain a short distance southwest of the foot of Hornaday Mountains. A view of this hole, from a photograph kindly supplied by Mr. Charles Sheldon, is given in Fig. 8. The diameter of the bottom is 3,600 feet and depth below

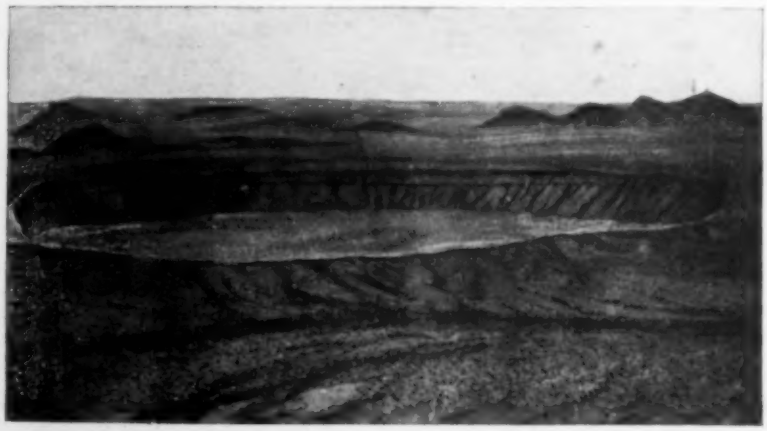

FIG. 8. MACDOUGAL CRATER, LOOKING SOUTHWEST FROM TOP OF HORNADAY MOUNTAINS, SONORA, MEXICO. Photo by C. Sheldon, 1916.

rim 400 feet. Its bottom is about 50 feet above sea level. The walls are mostly very steep and there is the usual surrounding rim of ejecta.

Lumholtz found a fine large circular crater in the lava plain a short distance northeast of Sierra del Pinacate, to which he has given the name Crater Elegante. It is six miles northeast of the central peak, near the edge of a plain covered by a thin lava sheet. He estimates its depth at 800 feet and a rough measurement gave a mile

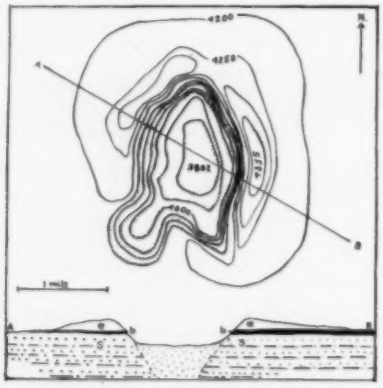

FIG. 9. CONTOUR MAP AND CROSS SECTION OF KILBURN CRATER, NEW MEXICO. Contour interval 50 feet, datum sea level. *s*, stratified sand; *b*, basalt; *e*, ejecta.

diameter. It is rimmed by a ridge rising about 150 feet above the surface of the plain. The bottom is flat and talus rises about half way up the sides. The view given by Lumholtz shows alternations of regularly bedded material.

The Afton craters in southern New Mexico, thirty miles north-

FIG. 10. LOOKING NORTHEAST INTO KILBURN CRATER NEAR AFTON, in southern New Mexico. The black streak is a thin sheet of lava much older than the hole. Note ranch to right of center of view. Photographed by W. T. Lee.

west of El Paso, described by Lee,[9] are closely similar to the craters in Mexico described above. They are in a level plain of thick stratified river deposits capped by a thin sheet of late basalt. One is a mile in diameter and about 150 feet deep; the other, two miles north, is two miles long and about 250 feet deep. Both are circled by rims of ejecta rising 10 to 200 feet above the plain. The inner slopes are steep and the outer slopes gentle. The ejecta, which lies on a fifteen-foot sheet of basalt, consists of sand, cinders, pumice, and blocks of basalt, and in part, especially near the base, shows irregular bedding with low outward slope. All came from below and was thrown out by an explosion, but the volume is much less than that of the craters. The configuration and structure of the larger crater is shown in Fig. 9. A view is given in Fig. 10.

Lee suggests that the explosion was caused by formation of steam generated by lava forced into the water-saturated sands.

The crater holding Zuñi Salt Lake is in the central-western part of New Mexico, about 75 miles south of Gallup. When I published a description of this feature in 1905,[10] I was inclined to believe that it was due partly to volcanic action and partly to subsidence caused by removal of underlying salt beds by solution. After comparing it with the conditions in other regions, I feel convinced it is an explosion crater. Some of the features are shown in Figs. 11 and 12. It is

FIG. 11. CONTOUR MAP AND CROSS SECTION OF ZUÑI SALT LAKE IN WEST CENTRAL NEW MEXICO. *e*, ejecta; *s*, cretaceous sandstone; *c*, cinder cone; *m*, mud and salt recently deposited by the lake.

[9] "Afton Craters of Southwestern New Mexico," by W. T. Lee, *Bull. Geol. Soc. Am.*, Vol. 18, pp. 211–220, pls. 3–4, 1907.

[10] "The Zuñi Salt Lake," by N. H. Darton, *Jour. Geol.*, Vol. 13, pp. 185–193, 1905.

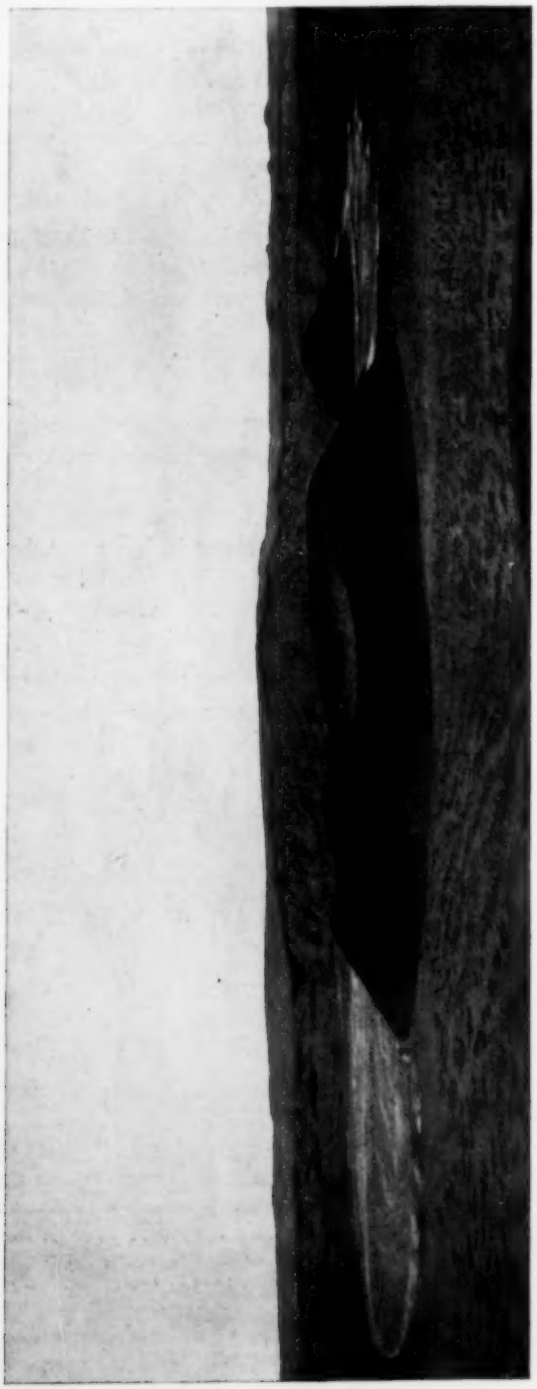

FIG. 12. LOOKING NORTH ACROSS THE CRATER HOLDING ZUNI SALT LAKE, NEW MEXICO. Large cinder cone with crater is in center; walls and plateau of Cretaceous sandstone surmounted by encircling ridge of ejecta, in mid-distance.

FIG. 13. BIRD'S-EYE VIEW OF CRATER MOUND, ARIZONA. Looking northwest San Francisco Mountains in the distance to the right.

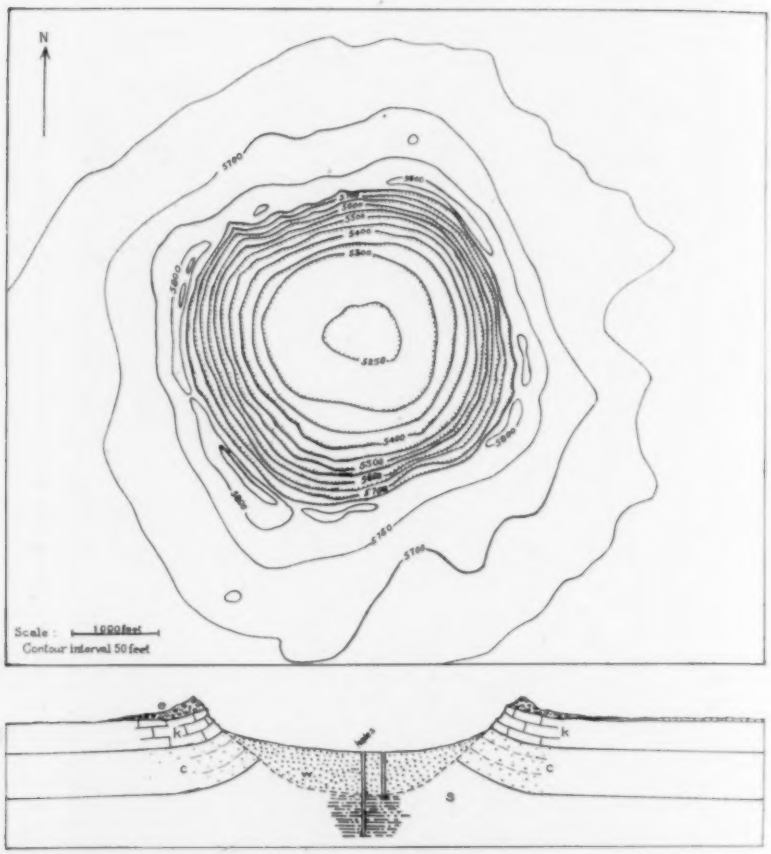


FIG. 14. CONTOUR MAP AND CROSS SECTION OF CRATER MOUND, ARIZONA. *e*, ejecta; *K*, Kaibab limestone; *C*, Coconino sandstone; *S*, Supai red sandstone; *w*, sand, etc.

about a mile in diameter, 150 feet deep, and encircled by a wide rim of ejecta consisting mainly of fine scoria containing fragments of the sedimentary rocks which underlie the region. Part of the material is stratified and cross bedded. The walls of the crater are Cretaceous

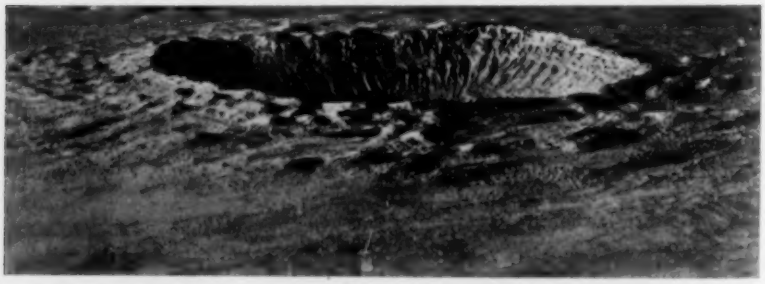

FIG. 15. A MODEL OF CRATER MOUND, ARIZONA. Constructed for G. K. Gilbert from a detailed topographic map by Marcus Baker.

FIG. 16. CRATER REMARKABLY LIKE CRATER MOUND IN APPEARANCE, caused by explosion of a "Mine" in the trenches in northern France in 1915.

sandstone, in part capped by a lava sheet of moderate antiquity. From the lake occupying part of the center of the crater rise two small cones of scoria, one with deep crater, and evidently very recent. The ejected material covers a wide area on the rim and beyond, and while it is much too small in volume to fill the crater, probably a large amount has been

FIG. 17. PART OF THE GREAT RIM OF FRAGMENTS OF LIMESTONE AND SANDSTONE EJECTED FROM CRATER MOUND, ARIZONA. Photo by G. K. Gilbert. Many of the masses weigh more than 5,000 tons, the largest 20,000 tons and the total amount of ejecta is about 250 million tons or approximately sufficient to fill the hole.

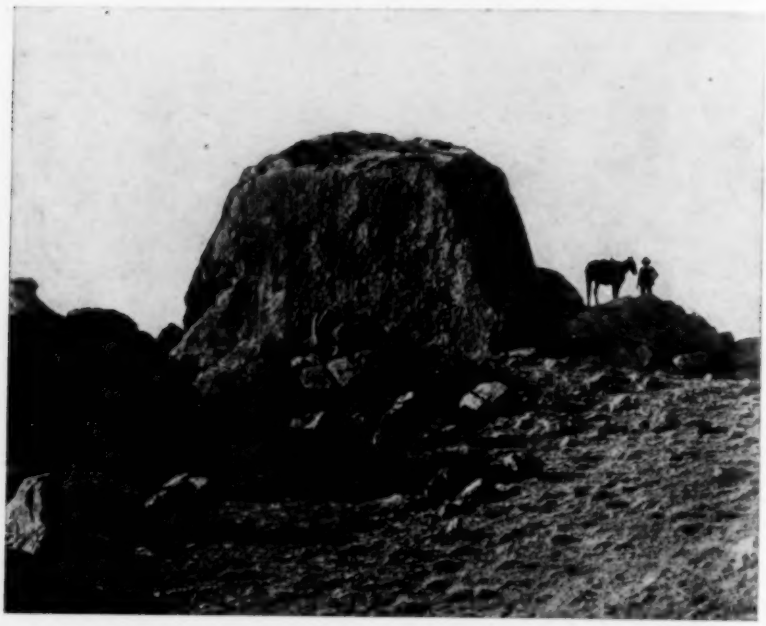

FIG. 18. LARGEST BLOCK IN THE EJECTA ON RIM OF CRATER MOUND, ARIZONA. A mass of limestone 60 feet in diameter weighing about 20,000 tons. Photo by G. K. Gilbert.

removed by erosion. Undoubtedly its bedded condition was caused by a simultaneous outburst of water.

Crater Mound, or Coon Butte as it was originally named, is so well known that I will not review it in detail and there is nothing new to add to previous descriptions.[11] Some of the salient features are shown in map and cross section, Fig. 14, and the views in Figs. 13, 15, 17 and 18. Its origin has not been ascertained and it remains one of the greatest enigmas in nature. The idea that it was caused by impact of a meteoric iron 50 to 100 feet in diameter has not yet been substantiated by borings, shaft and the survey of magnetic declination. It is interesting to compare this crater with the illustrations of explosion craters given above and the close similarity of many features is very suggestive in connection with Gilbert's original suggestion that Crater Mound was caused by a steam explosion.

[11] Gilbert, G. K., "The Origin of Hypotheses Illustrated by the Discussion of a Topographic Problem," Geol. Soc. Wash., Presidential Address, 1895, and *Science*, N. S., Vol. 3, pp. 1–12, 1896. Barringer, D. M., and Tighlman, B. C., "Coon Mountain and Its Crater," *Phil. Acad. Sci., Proc.*, 1906, pp. 861–914. Merrill, G. B., "The Meteor Crater of Canyon Diablo, Arizona. Its History, Origin and Associated Meteoric Irons," *Smith. Miscell. Coll.*, Vol. 50, Pt. 4, pp. 461–498, 1908. Barringer, D. M., "Meteor Crater in Northern Central Arizona," *Nat. Acad. Sci.*, Nov. 16, 1909, 24 pp., pls. Darton, N. H., "A Reconnaissance of Parts of Northwestern New Mexico and Northern Arizona," U. S. Geol. Survey, Bull. 435, 1910.

# THE RELATION OF MALARIA TO CROP PRODUCTION

By D. L. VAN DINE

BUREAU OF ENTOMOLOGY, UNITED STATES DEPARTMENT OF AGRICULTURE

THE principal effects of malaria upon farming are a reduction in the net profits on the crops grown and reduced values from the non-development of farm lands. Herrick (1903) mentions these losses, as applied to southern agriculture, and Howard (1909) emphasizes the economic loss from malaria by figures which are startling. He estimates that there is an annual loss in the United States through this disease of not less than $100,000,000.

The rural nature of malaria places the larger portion of the loss from the disease upon the farming class. The disease is more prevalent in the south than in other regions of the United States. The higher prevalence in the south is due to the larger areas of swamp and undrained lands, and lands subject to overflow which offer favorable breeding-places for the mosquitoes that convey the disease, to the longer season of high temperatures which favors mosquito development and which increases the length of the active season of the disease, and to the presence in larger numbers of an indifferent race which is tolerant of the disease. Although the losses from malaria have been appreciated for many years, the exact manner in which the disease operates against farm profits is not generally understood.

In 1913 the Bureau of Entomology undertook a detailed study of the relation of malaria to agriculture in the south. The ultimate object of the study is the prevention of malaria on the farm. The investigation is based on the idea that the prevention involves measures for the control of malaria mosquitoes which are practicable under the usual farming conditions. In the absence of definite information on the relation of the disease to farming, the primary work dealt mainly with the exact manner in which malaria operates against the net profits from farm crops. The study is an intensive one and its scope extends no further than the strictly agricultural and biological phases of the problem. The effort is to obtain concrete and fundamental information as a basis for an extensive application of measures for prevention. It is believed that the first step is to secure definite data on the manner in which malaria affects agriculture.

During the course of the investigation it has been determined that the important losses from malaria on a plantation are sustained through the loss in time and the reduced efficiency of the labor at the season of the year when the labor is most needed to work and to harvest the crops.

The prevailing system of plantation labor in the south is the negro tenant system, and the prevention of malaria among the tenants is considered the most important point in the problem of preventing the disease on a plantation. In the tenant system, the family is the unit in contrast to the day-wage system, where the individual is the unit. The family was, therefore, made the unit in the study.

The figures in this paper are based on the conditions that obtained during the season of 1914. The survey work included a detailed study of the 74 tenant families on a plantation and the amount of malaria among them in a region where the plantation operations and endemic malaria are typical. The plantation cultivated 1,800 acres of land, 1,191 acres by the tenant system and 609 acres under the direct supervision of the plantation management by labor drawn from the tenant families on a day-wage basis. The tenants averaged 16 acres per family. The 74 families show a total of 299 individuals, or an average of 4 persons per family.

The crops grown on the plantation consisted of 743 acres of cotton and 448 acres of corn under the tenant system and 80 acres of cotton, 209 acres of corn, 200 acres of oats, 70 acres of cow-peas and 50 acres of lespedeza hay under the day-wage system.

All time was reduced to adult time or man days of labor. The time of a male over 18 years of age was figured as full time, a male from 12 to 18 years as one half adult time and from 8 to 12 years as one fourth. The time of a female was figured as one half the time of a male. No account was taken of the time under 8 years of age. Reducing all the available labor on the plantation to adult time, there is an equivalent of 2 adults to each of the 74 tenant families.

The actual time lost through malaria consisted of 970 days for those treated by the plantation physician, 487 days in those cases not reporting to the physician, and 385 days lost by non-malarial members of the families in attending those who had the disease. There was a total loss of 1,842 days. This reduced to adult time, not taking account of illness in members of the families under eight years of age, amounts to 1,066 days of adult time from May to October, inclusive. The time lost averaged 14.4 adult days for each family. There were 166 cases of malaria in 138 persons out of the total of 299 members of the tenant families. There was a loss of time equivalent to 6.42 adult days for each case of malaria. The seasonal distribution of the cases of malaria was as follows: May, 15 cases; June, 31 cases; July, 25 cases; August, 38 cases; September, 36 cases, and October, 21 cases. The number of adult days lost through malaria, then, is 96 days for May, 199 days for June, 161 days for July, 244 days for August, 231 days for September and 134 days for October.

The effect of loss of time upon the crops can be measured by the

ratio of the time lost through malaria to the difference between the available labor and labor requirements of the crops. It must be conceded that any loss of labor from any cause in the face of any surplus labor that exceeds the time lost, can not be considered as operating against the crops. In the case of no surplus labor, or an actual deficiency, any time lost through malaria reacts at once upon the crops, the seriousness of the neglect to the crops depending upon the period in the planting, cultivating or harvesting the crops that the lost time occurs. It will be shown that the time lost through malaria during at least four months of the year falls at periods when there is a deficiency of labor and when the demands of the crops for labor are greatest. For cotton, the principal crop, these periods are chopping and hoeing, boll-weevil control and picking. Any neglect at these periods is a very serious matter and might mean total failure of a crop.

The available days for field work depend not only upon the number of adult laborers on the plantation, but also upon the available days per month when field work is possible. These two factors decide the available days of adult labor for field work. Mr. M. B. Oates of the Office of Farm Management of the Department of Agriculture has furnished the writer the following estimate of available days per month for field plantation work as determined by a study of estimates obtained by him from 50 plantation managers in the Red River region of northwest Louisiana.[1]

| Month | Days | Month | Days | Month | Days | Month | Days |
|---|---|---|---|---|---|---|---|
| Jan..... | 12.0 | April..... | 15.3 | July..... | 21.5 | Oct..... | 19.7 |
| Feb..... | 11.9 | May..... | 18.3 | Aug..... | 21.0 | Nov..... | 16.9 |
| March... | 14.5 | June..... | 19.1 | Sept..... | 19.4 | Dec..... | 12.6 |

The fallacy of figuring total days of adult labor per month on a basis of a 30-day month is evident. The factors of Sundays, holidays and climate determine the number of days available for field work during any month. The error would be as great to reduce all labor on the plantation to terms of adult labor and use this figure in obtaining the days of adult labor available. With 74 families averaging 2 adults per family there would be indicated a total of 148 adult days for every day in the year, 4,440 days adult labor available per month or the great total of 53,280 man-days of labor per year. Mr. Oates, on the basis of estimates from 72 plantations, finds that in this region 13.29 adult days of man labor, not including horse labor, are required per acre of cotton. On this basis the above figure shows that this plantation has an amount of labor sufficient to work over 3,200 acres of cotton, a condition which does not exist. The above table by Mr. Oates eliminates the error in

[1] The region included in the estimates is within the 50-inch rain belt. Madison Parish, where this study is located, has a normal rainfall of 51 inches.

days available for field work. It remains to consider the error in number of adults available for labor.

The object is to determine the relation of time lost through malaria to the total time available and to the time required by the crops. In considering the time available it will be necessary to eliminate the effect of malaria upon the efficiency of the labor. Howard (1909) estimates that one fourth of the productive capacity of an individual suffering with an average case of malaria is lost. One hundred and thirty-eight persons out of a total of 299 suffered from malaria during the crop season. Not taking account of the cases in children under 8 years of age and the time lost by adult non-malaria persons in attending those who were sick, the equivalent of the time of the malaria people is equal to the time of 74 adults. A reduction of 25 per cent. in the efficiency of 74 adults equals the total loss of the time of 18.5 adults. An average of 2 adults per family would indicate a loss equivalent to the total time of 9.25 families.

On the basis that every man, woman and child worked every available day in the field there would be available the time of 64.75 families. To figure on this basis would be as great an error as it would be to figure that there were 30 days available for field work every month in the year. There would be no day when every available person over 8 years of age would be in the field and all the persons in the field would not put forth maximum effort every day throughout the year. It is estimated that for these reasons the available labor would be reduced at least 25 per cent. This would mean that instead of 64.75 families, there would be only 48.57 families available. With an average of 2 adults per family, there appears to be available the equivalent of 97.14 adults. However, other factors act to reduce the available labor. Account must be taken of those who have passed the age limit for work in the field, the "pensioners" of the plantation. A funeral will keep practically all the laborers out of the field for all or a part of a working-day. Other diseases aside from malaria keep the laborers at home on working-days. It is estimated that the equivalent of one adult out of every ten would not be available for these reasons. The available man labor on the plantation has been figured on the basis of 90 adults.

Taking 90 adults as representing the available labor and using Mr. Oates's figures on the days available per month for field work, we have the following man days available per month for field work on this plantation.

| Month | Days | Month | Days | Month | Days | Month | Days |
|---|---|---|---|---|---|---|---|
| Jan..... | 1,080 | April..... | 1,337 | July..... | 1,935 | Oct..... | 1,773 |
| Feb..... | 1,071 | May..... | 1,647 | Aug..... | 1,890 | Nov..... | 1,521 |
| Mar..... | 1,305 | June..... | 1,719 | Sept..... | 1,746 | Dec..... | 1,134 |

The field operations and the man labor requirements for cotton, corn and oats in north Louisiana are shown in the following table which has been prepared from figures which were also furnished by Mr. Oates.

FIELD OPERATIONS AND MAN LABOR REQUIREMENTS FOR CROPS[2]

| Crop | Operations | Season (Average) | Days Labor per Acre |
|---|---|---|---|
| Cotton | Cut stalks | Dec. 28 to Feb. 4 | .13 |
| | Break and bed | Jan. 14 to Mar. 16 | .68 |
| | Harrow or drag | Feb. 6 to Mar. 24 | .14 |
| | Plant | Mar. 31 to Apr. 19 | .13 |
| | Cultivate and hoe | Apr. 13 to Aug. 4 | 5.43 |
| | Pick and haul | Aug. 29 to Dec. 7 | 6.78 |
| | Total for cotton | | 13.29 |
| Corn | Cut stalks | Dec. 26 to Feb. 3 | .12 |
| | Break or bed | Jan. 3 to Mar. 2 | .80 |
| | Harrow and drag | Feb. 9 to Mar. 20 | .16 |
| | Lay off rows | Feb. 21 to Mar. 19 | .13 |
| | Plant | Mar. 5 to Mar. 29 | .14 |
| | Cultivate | Mar. 26 to June 21 | 1.21 |
| | Thin or hoe | Mar. 24 to June 18 | 1.07 |
| | Plant peas | May 28 to June 18 | .12 |
| | Harvest | Sept. 13 to Nov. 3 | .84 |
| | Total for corn | | 4.59 |
| Oats (threshed) | Break | Sept. 21 to Nov. 8 | .64 |
| | Harrow | Sept. 25 to Nov. 8 | .22 |
| | Sow or drill | Oct. 11 to Nov. 16 | .09 |
| | Cut | May 28 to June 9 | .16 |
| | Shock | May 28 to June 9 | .32 |
| | Haul and thresh | June 20 to July 10 | .71 |
| | Haul grain | June 22 to July 15 | .19 |
| | Total for oats | | 2.33 |

As the labor involved in the control of the cotton boll weevil must be considered in this study, the period for this operation and the labor required are necessary. These have been estimated for this region by Mr. W. D. Hunter. The period of the operation averages from May 1 to June 30. The labor required is equal to at least one third of the labor requirements for hoeing cotton. This amounts to 1.12 man days labor per acre for boll-weevil control work.

The accompanying chart shows the seasonal distribution of the labor, by crops, from the estimates of averages by Mr. Oates, including the operation for boll-weevil control in cotton furnished by Mr. Hunter. (See chart I.). No account has been taken of the 70 acres of cow-peas and the 50 acres of lespedeza hay in arriving at the labor requirements

[2] The figures on cotton and corn are determined from estimates by 72 planters of northwestern Louisiana. Those on threshed oats are from estimates of 9 planters in the same region. The region is in the same rain and frost belts as the one in which this study is located.

on this plantation, as figures on these crops are not available for this particular region.

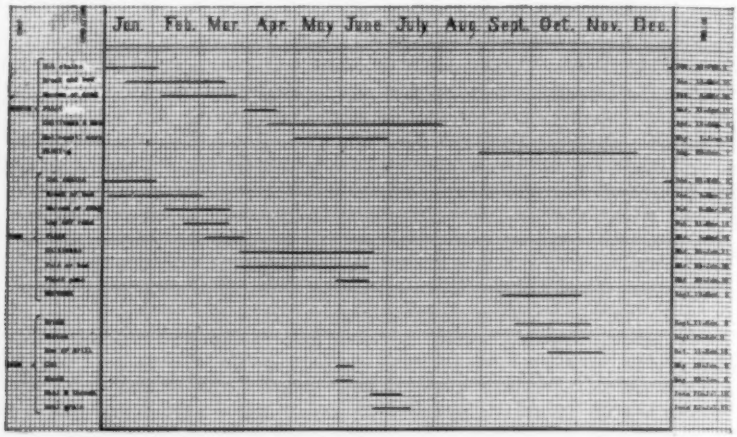


CHART I.

The following table gives the labor requirements on this plantation, distributed in terms of days of adult labor required per month, for 823 acres of cotton, 657 acres of corn, and 200 acres of oats.

As an example, the operation of cutting stalks in cotton fields will serve to show how this distribution was made. Cutting stalks requires .13 man days per acre. On 823 acres this would amount to a total of 107 days. The period when this work is done is from December 28 to February 4. On the basis of 12.6 days during December when field work is possible, there would be available 1.21 days for field work for the 3 days in December. There would be 12 days available for January and 1.7 days for the 4 days in February. The 107 days of adult labor required would have to be done in a period of the sum of these available days, or a total of 14.91 days. To do this would require the time of 7.17 adults. By assigning the days per month on the basis of the days available per month for field work, there is obtained a requirement of 9 days of man labor in December, 86 in January and 12 in February for cutting stalks. The operations for all crops were figured in this manner.

The accompanying chart (see chart II.) illustrates the relation of malaria to crop production by comparing the available labor, the labor required for the crops, including the labor for boll-weevil control in cotton, with the time lost through malaria. It shows that malaria is a serious handicap to the plantation during the months of May, June, September and October. During these months the operations are cultivating, hoeing, boll-weevil control and harvest. Maximum labor is required during all of these periods. There is a total loss of 660 adult days through malaria, in excess of any surplus time, during these 4 months.

DAYS ADULT LABOR REQUIRED FOR CROPS, DISTRIBUTED BY MONTHS[3]

| Crop | Operations | Jan. | Feb. | March | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cotton | Cut stalks | 86 | 12 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 9 | 107 |
| | Break and bed | 142 | 257 | 161 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 560 |
| | Harrow or drag | ... | 52 | 63 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 115 |
| | Plant | ... | ... | 5 | 102 | ... | ... | ... | ... | ... | ... | ... | ... | 107 |
| | Cultivate and hoe | ... | ... | ... | 551 | 1,164 | 1,216 | 1,367 | 171 | ... | ... | ... | ... | 4,469 |
| | Pick and haul | ... | ... | ... | ... | ... | ... | ... | 112 | 1,614 | 1,638 | 1,406 | 810 | 5,580 |
| | Total for crop | 228 | 321 | 229 | 653 | 1,164 | 1,216 | 1,367 | 283 | 1,614 | 1,638 | 1,406 | 819 | 10,938 |
| | Boll weevil control | ... | ... | ... | ... | 451 | 471 | ... | ... | ... | ... | ... | ... | 922 |
| | Total for cotton | 228 | 321 | 229 | 653 | 1,615 | 1,687 | 1,367 | 283 | 1,614 | 1,638 | 1,406 | 819 | 11,860 |
| Corn | Cut stalks | 62 | 7 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 10 | 79 |
| | Break or bed | 43 | 448 | 35 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 526 |
| | Harrow or drag | ... | 49 | 56 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 105 |
| | Lay off rows | ... | 29 | 56 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 85 |
| | Plant | ... | ... | 92 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 92 |
| | Cultivate | ... | ... | 38 | 247 | 295 | 215 | ... | ... | ... | ... | ... | ... | 795 |
| | Thin or hoe | ... | ... | 48 | 225 | 270 | 160 | ... | ... | ... | ... | ... | ... | 703 |
| | Plant peas | ... | ... | ... | ... | 9 | 70 | ... | ... | ... | ... | ... | ... | 79 |
| | Harvest | ... | ... | ... | ... | ... | ... | ... | ... | 187 | 336 | 29 | ... | 552 |
| | Total for corn | 105 | 533 | 325 | 472 | 574 | 445 | ... | ... | 187 | 336 | 29 | 10 | 3,016 |
| Oats (Thrashed) | Break | ... | ... | ... | ... | ... | ... | ... | ... | 25 | 84 | 19 | ... | 128 |
| | Harrow | ... | ... | ... | ... | ... | ... | ... | ... | 5 | 31 | 8 | ... | 44 |
| | Sow or drill | ... | ... | ... | ... | ... | ... | ... | ... | ... | 11 | 7 | ... | 18 |
| | Cut | ... | ... | ... | ... | 8 | 24 | ... | ... | ... | ... | ... | ... | 32 |
| | Shock | ... | ... | ... | ... | 15 | 49 | ... | ... | ... | ... | ... | ... | 64 |
| | Haul and thrash | ... | ... | ... | ... | ... | 68 | 74 | ... | ... | ... | ... | ... | 142 |
| | Haul grain | ... | ... | ... | ... | ... | 12 | 26 | ... | ... | ... | ... | ... | 38 |
| | Total for oats | ... | ... | ... | ... | 23 | 153 | 100 | ... | 30 | 126 | 34 | ... | 466 |
| Summary | Total for cotton | 228 | 321 | 229 | 653 | 1,615 | 1,687 | 1,367 | 283 | 1,614 | 1,638 | 1,406 | 819 | 11,860 |
| | Total for corn | 105 | 533 | 325 | 472 | 574 | 445 | ... | ... | 187 | 336 | 29 | 10 | 3,016 |
| | Total for oats | ... | ... | ... | ... | 23 | 153 | 100 | ... | 30 | 126 | 34 | ... | 466 |
| | Grand total | 333 | 854 | 554 | 1,125 | 2,212 | 2,285 | 1,467 | 283 | 1,831 | 2,100 | 1,469 | 829 | 15,342 |

Making allowance for the time lost on days when field work was not possible, there was a loss of 420.75 adult days which amounted to actual neglect. During these 4 months there are 76.5 days available for field work. The loss represents that of 5.5 adults out of a total of 90 available adults. The actual available adult time per family is 1.21 adults. The time lost is the equivalent to that of 4.54 families. Adding to this the effect of malaria on the efficiency of the labor, amounting to the time of 9.25 families, the survey shows that in the absence of malaria this plantation could operate with the same net returns on the labor of 60.21 tenant families, instead of the 74 families required in the presence of malaria.

[3] On the basis of 823 acres of cotton, 657 acres of corn, and 200 acres of oats.

Herrick (1903) says, in writing of the effect of malaria upon southern agriculture, that "to induce a people to use a remedy it must first be shown that a remedy is very much needed." It is the purpose of the Department of Agriculture to place the prevention of malaria on the farm upon a business basis. It remains to show what malaria means to a cotton planter in so many dollars and cents.

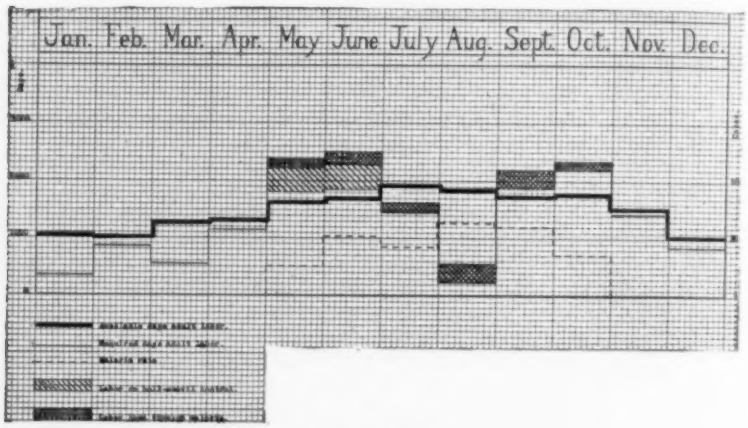


CHART II.

Each family cultivated an average of 16 acres. The plantation depended upon the tenants for labor to cultivate an average of 8.23 acres each on the day-wage basis. This amounts to a total of 24.23 acres to be cultivated by the labor represented in each tenant family, an equivalent of 13.51 acres of cotton. The total loss of the time of 13.79 families is equal to that of the total crop on 186.3 acres of cotton. With an average yield of one half of a bale of cotton per acre, this would equal a total loss of 93.15 bales of cotton. Allowing $70 a bale for the lint and seed, this would amount to $6,520.50.

The amount of share varies under the tenant system. In general, though, the plantation management furnishes the land, cabin, mules, feed, implements and fertilizer, and advances to the tenant subsistence and seed. Under this arrangement the plantation receives one half of the crop. Against all this the tenant places only his labor. Any reduction in the yield falls largely upon the owner, since he loses not only his one half of the crop, but a proportion of the advances. In a failure of the crop, the owner loses his one half and the use of the land, cabin, mules and implements, plus all advances to the tenant. The most that the tenant stands to lose is his labor. Not allowing for days when field work was impossible and on the basis of the prevailing day wage of $1.00 per day, this amounts to $660. The net loss to the owner is then $5,860.50.

The actual available adult time in each family equals 1.21 man days. The actual number of available days for field work during the four months under consideration equals 76.5 days. A loss of time equivalent to the total loss of 13.79 families is equal to the loss of 1276.47 man days during these periods, when there was no surplus labor. There were 420.75 days lost through sickness and a loss of 855.72 days due to reduced efficiency. Each day of neglect amounted to a total loss of $5.11, being a loss of $4.11 to the owner and $1.00 to the tenant. The conclusion is that a loss equivalent to one day of man labor through malaria on this plantation, when the crops were in need of attention, and when there was no surplus labor, amounted to a net loss of $5.11 in the crop returns. Approximately $2,200 was lost through sickness and $4,300 through inefficiency from malaria.

The above survey was made in Madison Parish, Louisiana. The common house-frequenting *Anopheles* in this region is *Anopheles quadrimaculatus* Say. *Anopheles punctipennis* Say is common in nature while *Anopheles crucians* Wied., was encountered only in very limited numbers. All three forms of the malaria parasite have been found to occur in this region, namely, tertian, estivo-autumnal and quartan, prevailing in the order named. The work was done in cooperation with the Maxwell-Yerger Co., Dr. Wm. P. Yerger, and Mr. Alexander Clark, Manager of Hecla plantation, Mound, La. The *Anopheles* determinations were made by Mr. F. Knab, of the U. S. National Museum. The blood examinations were made by Mr. J. K. Thibault, Jr., of this Bureau. Mr. Oates, of the Office of Farm Management of this department, furnished the data on the periods of the plantation operations, the available days per month for field work and the labor requirements of the crops.

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# STEPHEN HALES, THE PIONEER IN THE HYGIENE OF VENTILATION

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IT has happened again and again in the history of discovery that some of the most important advances in a particular science have been made by persons not engaged in the professional pursuit of that subject.

No doubt the formal recognition of public health as a science is of quite recent date, but there have always been those who have recognized the paramount claims of that branch of knowledge now embodied as hygiene or preventive medicine. Medical men, as might be expected, have in all ages been interested in measures that tended to the health of the community as distinguished from that of the individual merely. But persons who were not medical men at all have from time to time either made suggestions of permanent value as touching the health of the people, or, going farther, have actually made contributions to the science of public health of such a kind that without these progress in that science would have been very greatly delayed. The truth of this is strikingly brought out in the life of one of the name of Hales, a clergyman of the Church of England, a man who had neither studied medicine nor taken a medical degree, but who was, nevertheless, the first person in England to make any serious attempt to provide for the systematic supply of fresh air to places where impure air could not leave by natural means. The Reverend Stephen Hales, M.A., D.D., F.R.S., was *the* pioneer in the hygiene of ventilation.

There have been parallel cases in other sciences: the Marquis of Worcester, though not an engineer, invented the steam pump; Leeuwenhoek, though not a member of the medical profession, made discoveries of the most fundamental order in physiology and microscopical anatomy; Captain Cook, though neither a physician nor a biologist, investigated from the practical side the causes and incidence of scurvy with such excellent results to the health of sailors that he was awarded the Copley medal of the Royal Society in 1776; Lady Mary Wortley Montagu, the wife of the British ambassador at Constantinople, introduced inoculation for smallpox into England; Helmholtz, though not an oculist, invented the ophthalmoscope; Pasteur, though not a medical practitioner, introduced inoculation of attenuated virus for the cure of hydrophobia; and, in our own day, Metchnikoff, trained as a scientific zoologist, has exercised a most far-reaching influence on the doctrines of bacteriology and practical medicine.

Mankind did not arrive apparently by the aid of "the light of nature" alone at a knowledge of the supreme importance of ventilation. To *some* results of great practical importance, purely natural instincts have guided mankind; for there are certain things known to be poisonous when eaten, certain waters are declared non-potable; but, as regards the quality of the air to be breathed and what constitutes impure air, the natural teachings are exceedingly ambiguous. The natural man is all right so long as he remains under the open heaven, but as soon as he surrounds himself with four walls he seems not to know that he must constantly keep changing the invisible air around him. No doubt it is because it is out of sight that air is also out of mind: certain it is that at the present moment there are vast multitudes of people who never conceive of air as a real thing, as real as their meat and drink and just as necessary to be kept fresh. Cave-man had no trouble with ventilation, nor had those in "the tents of Shem"; but from the day that man began to sleep inside stone and lime he had to face the problem, although he was not in the least conscious of it, how could the foul air be removed and the pure air brought in without producing a chilling draught. To do this is to ventilate. The unpleasantness and even danger to health of this movement of the air was, doubtless, much of the reason why he was so long in grappling with the problem even when he had awakened to its existence. Not that he has even now by any means consciously solved the problem. There are millions of houses over the length and breadth of the earth entirely unprovided with the means of ventilation; heated they may be, ventilated they are not. With their closed stoves and their windows shut, such rooms are as devoid of the means of changing the air in them as is an oven. The least fresh of rooms in England with their open chimney, even when no fire is burning, and with "sash" windows capable of being easily opened from the top without causing a draught, may be said to be exceedingly well ventilated as compared with the typical room one finds on the Continent of Europe. All living things vitiate air on breathing it even once; all living things subsist by means of the absorption of oxygen, that is, of fresh air: this was what Hales grasped, and he saw how very far many members of the community were from being in a position to command at all times a supply of this absolutely necessary though perfectly invisible material. Hales in England and Leeuwenhoek in Holland, neither of them medical men, were, about the year 1720, probably the two persons who saw more clearly than any one else in Europe the prime necessity for ventilation, that is, the constant change of the air in the neighborhood of living beings.

Hales did a very great deal else in science besides devising ventilators; he was a pioneer in the experimental method in both vegetable and animal physiology quite a hundred years before physiology as an experimental science existed in England. But in regard to the public

health it is not too much to say that as a benefactor of mankind, he is conspicuous in the first half of the eighteenth century. It would be difficult to mention the name of any other person co-equal with his. We know very little indeed of his capabilities as a pastor of men's souls, but it is certain that he had great solicitude for their bodies; he introduced a water-supply into the village of Teddington, and it appears that he actually contrived to ventilate its parish church. His pamphlet against the abuse of alcohol is probably the first of its kind in English—"A friendly admonition to the drinkers of gin, brandy and other spirituous liquors." This, published in 1734, alone enables him to rank as a pioneer in the advocacy of measures of practical hygiene. Hales had grasped the very essence and kernel of the principle of ventilation, *that air must be changed,* whether air for plants or for animals, air over corn in granaries or over water stored for drinking purposes or air enclosed in hot-houses, or air in mines, or in the holds of ships, or in prisons, or around timber or gunpowder; air must be changed. He knew that fresh air was inimical to putrefaction, mouldiness of every kind; he invented an apparatus for blowing air through drinking water stored in ships. On long voyages in the "old wooden walls" such water became putrid: Hales showed that it could be made sweet again if only enough air could be blown through it. We *now* know what was going on, namely the oxidation of organic matter; but Hales died in 1761, thirteen years before oxygen was discovered. It is interesting to note that Hales had the most definite conceptions as regards this necessity for oxygen in ventilation, without knowing what it was that sustained life, and without knowing, in anything like its fulness, the meaning and importance of Joseph Black's discovery that animals exhaled carbon dioxide from their lungs. Black's discovery was published in 1754, some seven years, indeed, before Hales died; but it is certain that Hales was not indebted to Black; on the contrary, it is not as widely known as it might be that Black was profoundly indebted to Hales. Black wrote:

> **I was partly led to these experiments by some observations by Dr. Hales, in which he says that breathing through diaphragms of cloth dipped in alkaline solution made the air last longer for the purposes of life.**

Before we further examine the value of the contributions made by Hales to the hygiene of ventilation, it will be well to trace the order of the discoveries of the gases of the atmosphere without which, of course, in the long run no scientific basis for the study of the problems of ventilation could have been arrived at. Carbon dioxide was discovered under the name of gas sylvestre by the Belgian chemist J. B. van Helmont (1577 to 1644) about the year 1640. Having burnt a known weight of wood, he noticed that only about one sixtieth of the original weight remained in solid form. The other fifty-nine sixtieths he regarded as

something volatile to which he gave the name of "gas," a word he coined on purpose to designate this "spirit" of wood and other kindred spirits. Gas sylvestre, because it came from or was produced by the burning of wood, was the first name under which carbon dioxide became a chemical concept in the minds of men of science.

The next contributions to accurate notions about breathing and hence about the necessity of ventilation, were made by Thomas Willis (1621 to 1675), who distinctly laid it down that three things cooperated in the act of respiration. These were: (1) a free and continuous access of air; (2) a constant supply of combustible material, and (3) the necessity for the continuous removal of the products of the combustion, for Willis clearly identified the burning of a flame in air and respiration in a living animal body; it is certain that he believed that they were chemically the same thing. It was in 1660 that the Hon. Robert Boyle, who did so much for the early mathematico-physical study of the atmosphere and of gases, performed the fundamental experiment as regards ventilation, namely, to exhaust the air around a living animal. He showed that long before the vacuum was perfect, a sparrow and a mouse had both died, and the flame of a candle had gone out. Boyle also understood that there was something besides watery vapor that rendered expired air unfit for further breathing by animals. G. A. Borelli about twenty years later was the first to estimate what we now know as the "tidal air," that is the quantity of air taken in and sent out at each breath, a most important datum as regards the supply of fresh air per person.

The Cornishman, Richard Lower, clearly perceived before 1669 that the blood in the lungs was arterialized by absorbing something from the inspired air, what we now know to be oxygen. Lower was also quite certain that the expired air was noxious and ought to be removed; were there no need for this change, he writes, "we should breathe as well in the most filthy prisons as amongst the most delightful pastures." Lower held it as an axiom that where a fire burns readily, there an animal can breathe easily. The full significance of Lower's conclusions was not grasped by his contemporaries; even so great a physiologist as Haller failed to see all that they involved.

The next step was taken also by an Englishman, an Oxford man of science, John Mayow. Working between 1668 and 1674, Mayow virtually discovered oxygen in a physiological sense. He named it "nitro-aerial particles," for he identified the substance which, absorbed from the air in breathing, produces animal heat, with the substance niter that appeared to be the cause of the combustion of gunpowder. Mayow died in 1679; and in England nothing was done as regards respiration or ventilation until Hales arose to rediscover much that Lower and Mayow had known well. In some respects Hales was less of a chemist than Mayow, but he caused hygiene to advance to a vastly greater ex-

tent because he applied what little theoretical knowledge he had to the solving of problems of very definite practical utility. He knew something of the work of his predecessors Borelli, Lower and Mayow. He knew that of his contemporary Boerhaave; but, much less technically learned than all of these, he became the pioneer sanitarian of the first half of the eighteenth century. He was not a physiological chemist like Lower and Mayow, but he was the discoverer of a method of sustaining respiration in the absolutely irrespirable atmospheres of coal-mines or burning houses. He suggested that the apparatus might be serviceable for divers. He was the father of all such as descend into "fire-damp" and "choke-damp" and "black damp" provided with an independent supply of air in an apparatus capable of absorbing the exhaled carbon dioxide. He was the Jubal of all such as handle rescue-apparatus. He was a pioneer in a great deal else that does not concern us now, for he was the first person in this or any other country to obtain by experiment on the living animal a demonstration of the magnitude of the pressure of the blood in arteries; and he is the father of vegetable physiology in England, and he is much else. But we must not imagine that, although Hales devised an artificial respiration apparatus, he was acquainted with all the properties of carbon dioxide. For just as Van Helmont in the seventeenth century worked with the carbon dioxide of combustion without being aware of all its properties, so Hales in the eighteenth worked with the carbon dioxide of respiration without realizing all that was involved in his researches. This sort of thing has happened again and again in science. Respiratory carbon dioxide was discovered by Professor Joseph Black at the University of Glasgow in 1754. In point of time nitrogen was the next constituent of the atmosphere to be identified: this was also by a Scotsman, Professor Daniel Rutherford (1749–1819) of the Chair of Botany at Edinburgh. The year of this was 1772, the man the maternal uncle of Sir Walter Scott. Within two years more, oxygen was separated by Joseph Priestley from mercuric oxide under the name of "dephlogisticated air." By 1775 Priestley had found that this gas supported both combustion and respiration. Had it not been for the phlogiston theory, to which he clung with fatal tenacity, Priestley would have been the undisputed discoverer of the gaseous basis of life; as a matter of fact, Lavoisier, as we are all aware, was the man who knew what he had got when by the end of 1774 he had isolated *oxygen* and so named it.

But we must not forget that Priestley also worked much on the properties of carbon dioxide, it was the gas he first studied near a brewery at Warrington. As early as 1772 he read a paper to the Royal Society showing experimentally that, while animal life could not be supported by this gas, plants, on the other hand, restored the wholesomeness to air rendered putrid by animal breathing. He also demonstrated that by both combustion and respiration the air loses one

fifth of its volume: for these researches Priestley received the Copley medal in 1773.

The details of the private life of Stephen Hales are neither numerous nor romantic. The son of Thomas, eldest son of Sir Robert Hales of Beckesbourn, Stephen was born in 1677 near the pleasant village of Beckesbourn in Kent, not far from Canterbury. His mother was Mary, daughter and heiress of Richard Wood, of Abbot's Langley. At the age of nineteen he went to Cambridge, being entered at Bene't College (now Corpus Christi), of which he became a fellow in 1703. In due time he graduated M.A. and he took his B.D. degree in 1711. His early scientific leanings may be inferred from his having studied anatomy, chemistry and botany as a recreation. Accompanied by William Stukeley, a fellow student, later M.D. and F.R.S., Hales is reported to have studied field botany on the Gog-Magog Hills and on Cherry Hunt Moor by the aid of Ray's catalogue of local plants, and also at this time to have made collections of fossils and of butterflies. It was as a student, too, that he contrived to make a cast in lead of the lungs of a dog. He did not neglect astronomy, for according to one account he constructed a "planetarium in brass" or, as it was later called, an "Orrery" on Newtonian principles. Having taken Holy Orders, Hales was presented in 1710 to the "perpetual curacy" of Teddington in Middlesex. Not long after he resigned his fellowship on being presented to the living of Porlock in Somerset; this he finally exchanged for that of Farringdon in Hampshire. The date of his marriage is uncertain: it is thought to have been in 1719; his wife died childless in 1721; Hales did not marry again. It was at Teddington that by far the greater number of his experiments were carried out. At his own expense he rebuilt the tower of the parish church of St. Mary's-in-the-Meadows. In 1718, at the comparatively early age of forty, Hales was elected into the Royal Society, and twenty-two years later was awarded the Copley medal—the highest honor in the gift of that learned body. Until within a year or two of his death he communicated the results of his manifold researches in the form of papers to the Royal Society. He published, however, in book form several treatises: his "Vegetable Statics" saw the light in 1726, and the "Hæmostatics" or Volume II. in 1733. Volume I. is dedicated to "His Royal Highness George Prince of Wales" and Volume II. "To the King's Most Excellent Majesty." This "George, Prince of Wales," and the "King's Most Excellent Majesty" are the same person, for in 1726 George I. was still reigning, but by 1733 his son George, who had been Prince of Wales, was now George II.

Although, then, Hales wrote extensively on vegetable and animal physiology, chemistry and medicine—for he discoursed on the alleged virtues of tar-water and investigated solvents for stone in the bladder—it is as a pioneer sanitarian that he must ever live in our grateful

remembrance. He did not occupy his time in calculations as to the number of cubic feet of air required per person per hour, but he designed a workable apparatus on the principle of the bellows for the purpose of abstracting air from places particularly badly situated as regards the changing of their air. The earlier forms were worked by hand, the later were driven by a windmill, their general design being much the same as that of bellows for church-organs. The velocity of outflow of air from the bellows, Hales expresses as 6¼ miles an hour, a little over 9 feet per second.

His first paper on the importance of ventilators in mines, hospitals, prisons and ships was read to the Royal Society in 1741, in which year an almost identical invention was announced by one Martin Friewald, "captain of mechanics" to the King of Sweden. So useful was this latter apparatus that the French government ordered an installation of it on all the ships of their navy. Not once or twice in the story of invention have important discoveries been made simultaneously and often in countries widely distant, as in the present instance. The title-page of the treatise in which Hales describes his invention reads thus:

> **A description of Ventilators whereby great quantities of fresh air may with ease be conveyed into mines, gaols, hospitals, workhouses and ships in exchange for their noxious air, and in preserving all sorts of grain dry, sweet and free from being destroyed by weevils both in granaries and ships . . . as also in drying corn, malt, hops, gunpowder &c and for many other useful purposes which was read before the Royal Society in May 1741.**

Truly it was not an age of succinct titles, but its length enables us to see that Hales had a clear idea of that one thing needful, namely, fresh in place of noxious air; he was under no doubt whatever that the air of mines, gaols, hospitals, workhouses and ships, left to itself, becomes noxious and must be changed. This is corroborated by the quotation from Milton which follows:

> **and God made**
> **The firmament expanse of liquid, pure**
> **transparent, elemental air.**

In this work he speaks of "the rancid vapors from human bodies"; from this it is not quite clear whether or not Hales was distinguishing respiratory carbon dioxide from the noxious vapors arising from the skin and lungs. We must at any rate remember, as has been already said, that he wrote without knowing of the discovery of respiratory carbon dioxide. It is certainly interesting to be told the very latest opinion as to the deleterious nature of breathed air is that it is not due to the carbon dioxide *per se,* but that the headache and distress are due to the moisture, the heat and the disagreeable, volatile, organic effluvia from the skin and lungs of the persons within the confined space. Without any technical chemical knowledge of the precise cause of impure air, Hales had grasped the far more important fact that

breathed air must be got rid of and sent outside into the ocean of the atmosphere.

It can not in fairness be alleged that those in authority were slow to avail themselves of the benefits of Hales's ventilators; but their adoption in the prisons, where the ventilation was excessively bad, was no doubt hastened by the deaths of the Lord Mayor of London, two Judges and an Alderman, all of whom became infected with gaol fever caught at the Old Bailey Sessions. "The Royal Society," wrote the late Sir William Huggins, "was called upon for advice and assistance. A committee was appointed to investigate the wretched state of ventilation in gaols. A ventilator invented by one of the committee was erected in Newgate, reducing at once the number of deaths from eight a week to about two a month. Of the eleven workman employed to put up the ventilator, seven caught the fever and died." There is not the slightest doubt that in those days to be sent to prison was the same thing as undergoing the death sentence of poisoning by foul air. Though Huggins does not mention Hales, it is certain he is the person alluded to as on the committee who introduced his ventilators into the prison. The version given by Peter Collinson in his sketch of the life of Hales (*Annual Register* for 1764) differs a little in one or two particulars: this writer states that in 1749 Hales's ventilators were installed in the Savoy prison by order of Mr. Henry Fox, later the first Lord Holland. Between the years 1749 and 1752 four prisoners died there of gaol fever as compared with between fifty and a hundred per annum previously. In the year 1750, out of two hundred and forty prisoners, only four died; and of these two died of smallpox and one of alcoholism, so that the salutary effects of Hales's installation were immediate and striking. In 1752 his ventilators actuated by a windmill and having ducts leading from twenty-four cells or wards were introduced into Newgate prison: as a result of this, Collinson says, the ratio of deaths after to those before the ventilation was as seven to sixteen, that is they had been reduced to less than 50 per cent. In 1753 Hales wrote an article in the *Gentleman's Magazine* on the applicability of his ventilators to army hospitals and to private houses. He also reported on their means in a smallpox hospital. Before his death his ventilators had been installed in the prisons at Winchester and Durham. In modern terminology, Hales ventilated by abstraction of foul rather than by propulsion of fresh air.

Hales's invention was greatly appreciated on board ship. Ships at this time were floating strongholds of death; between scurvy and ship fever due to poisoning by bad air, only the most robust men survived for any length of time. In 1755, Hales wrote a short but most interesting paper to the Royal Society, entitled "An account of the great benefits of ventilators in many instances in preserving the health and lives of people in slave and other transport ships." In this, Hales

speaks of "finding means to procure them fresh, salutary air instead of the noxious, putrid, close, confined, pestilential air which has destroyed millions of mankind in ships." He says "the principal cause of the sickness in ships is the noxious, putrid air; the obvious remedy is the exchanging that foul air for fresh by effectual means which are seldom discovered by dwelling only on objections." Hales further alludes to the "vulgar, false and groundless notion that they take up too much room . . . the men are eager to work them."

"Decay," he continues, "is wholly owing to damp, close, confined, putrid, corroding air, so the only remedy for this evil is the frequently changing the air among the timbers by plentiful ventilations." Hales published in this paper a letter dated London, September 25, 1749, from a Captain Thomson of the frigate *Success* which is most interesting reading:

> Our rule for ventilating was half an hour every four hours, but when the ventilating was sometimes neglected for eight hours together, then we could perceive, especially in hot weather, a very sensible difference by the neglect of it. All agreed the ventilators were of great service. The men did not need to be urged to work them. Two hundred men aboard for a year, pressed men from gaols, with distemper all landed well in Georgia. This is what I believe but few transports or any other ships can brag of, nor did I ever meet the like good luck before, which, next to Providence, I impute to the benefit received by the ventilators. . . . This certainly occasioned all kind of grain provisions to keep better and longer from weevels than otherwise they would have done, and other kinds of provisions received benefit from the coolness and freshness in the air of the ship which was caused by ventilation.

Hales then quotes a Mr. Cramond, who attributed the good health of his ship with three hundred and ninety-two slaves and Europeans, to the presence of the ventilators; twelve of the slaves died, but when taken on board they were all "ill of a flux." The next report is from a Captain Ellis, writing from Bristol, December 26, 1753. After lamenting the *vis inertiæ* of prejudice and ignorance, Ellis says:

> "It does honour to those noble and other worthy personages that join you in acts of such extensive humanity as the introduction of ventilators to hospitals, prisons, ships of war and transport &c as they necessarily render the miseries of the first more supportable, and the close and constant confinement of the others less prejudicial and fatal to their health and life.
>
> The ventilators were of singular service to us, they kept the inside of the ship cool, sweet, dry and healthy. The number of slaves I buried was only six, and not one white man of our crew (which was thirty-four) during a voyage of fifteen months, an instance very uncommon. The three hundred and forty negroes were very sensible of the benefits of a constant ventilation, and were always displeased when it was omitted."

Captain Ellis did better still in his next voyage in 1755, for not one of the three hundred and twelve slaves died, and these and all his crew to the number of thirty-six were landed alive and well at Bristol. Hales goes on to say that the Earl of Halifax (1716–1771)

told him of the great benefit derived from ventilators installed in transport-ships to Nova Scotia; the deaths in ventilated to those in non-ventilated ships being as one to twelve. Through soliciting the interest of the French man of science du Hamel de Monceau, Hales contrived to have his ventilators installed in certain prisons in France where English prisoners were confined. He jokingly said that he hoped that he would not be accused of assisting the enemy. The reverend sanitarian closes his paper with these words:

> They little consider that it is the high degree of putrefaction (that most subtle dissolvent in nature) which a foul air acquires in long stagnating which gives it that pestilential quality which is called the gaol-distemper, and a very small quantity or even vapour of this highly attenuated venom like the infection or inoculation for smallpox soon spreads its deadly infection. Ought not men therefore . . . to use their utmost endeavours to shun this pestilential destroyer by which millions of mankind have perished in ships.

Now this is a somewhat remarkable paragraph to have been written in 1755. It undoubtedly refers to typhus fever, known under all the following names: putrid fever, pestilential fever, ship fever, emigrant fever, hospital fever, and gaol fever. It was, for it is happily now quickly disappearing, the fever of bad sanitation, the scourge of unwashed, ill-fed, badly housed, neglected specimens of humanity. Even now its precise cause, whether coccus, bacillus or other parasite, is not known. The very latest suggestion is that it is an ultra-microscopical virus transmitted by some insect that infests persons of unclean skins. But the very fact that to-day we have not isolated the virus is a sufficient proof of its excessively elusive nature—a very attenuated poison indeed, as Hales says. Of course Hales did not know it as typhus fever: typhus, typhoid and relapsing fever were all confused until Sir William Jenner about 1850 clearly distinguished between the first two. With the rise of bacteriology, the microorganic origins of the last two have been established; the true cause of typhus has still to be discovered. While pathologists are still struggling over the precise cause of this fever, the practical sanitarians have almost banished it from Great Britain. Better feeding, more facilities for personal cleanliness, and above all a clearer appreciation of what ventilation means have co-operated in abolishing this horrid scourge; but let us never forget that the initial, intelligent stages of the war against it were undertaken by Stephen Hales.

Amongst other analyses Hales made was the analysis of the expired air. He evidently regarded death in explosions in mines and of the animals in the "grotto di cani" as being due to the same poisonous gas.

Besides attacking and solving the problem of ventilating such places as most urgently needed it, Hales devised a method whereby a person could enter an irrespirable atmosphere and continue to breathe,

if not absolutely pure air, such air as could sustain life for some minutes, long enough to enter a burning house or, as he suggested, a laboratory filled with noxious fumes. The mechanism was a bladder divided up into compartments by four diaphragms of flannel or linen soaked in a solution of potash or "sal tartar" capable, as we now know, of absorbing the respiratory carbon dioxide. A tube led from the far end of the bladder and, curving upwards, terminated in a mouthpiece near which were placed two valves, one allowing air to enter the near end of the bladder, the other preventing it from passing back into the far end. The nostrils had to be closed, as they have to be in all mouth-breathing forms of such apparatus. The receiver held between four and five "quarts of air"; Hales thought that with one gallon of air and four diaphragms, respiration could be supported for at least five minutes. He remarks, what we can readily believe, that there was much discomfort unless the valves worked easily.[1]

In view of the prominence which life-saving apparatus has attained at the present day, it seems exceedingly interesting to know that before 1726, a practical attempt had been made to construct an artificial rescue-apparatus. Hales himself contemplated its use not only in the foul air of mines, but by divers under water; it is, however, very doubtful whether the mechanism as he left it could have been used under water. This simple invention is the humble parent of the various ingenious life-saving apparatuses of the present day, the Fleuss, the Dräger, and others which enable a man to remain for upwards of two hours in atmospheres not merely poisonous, but actually deadly. As we have already seen, it was this invention of Hales that inspired Black to discover respiratory carbon dioxide.

As all men of science know, Stephen Hales may be said to have founded the science of experimental, botanical physiology; his observations by means of mercury manometers on the pressure exerted by the rising of sap in vines are classical. Although he was a pioneer, he fully acknowledged the work done in plant physiology by Mayow, Grew and Malpighi. His views regarding the transpiration of plants and their nourishment, and how they utilized some constituent of the atmosphere only under the influence of solar light, were all in advance of his time.

In animal physiology he was also a pioneer, for he was the first to ascertain the magnitude of the pressure of the circulating blood: this he did by opening the left crural artery of a living animal, the horse. His method was crude: he merely allowed the blood to rise as high as it could (8 ft. 3 in.) in a vertical tube partly of brass and partly of glass; but the principle of his method is even now most fruitfully used in practical medicine. He studied the general physiology of the blood-pressure in arteries and in veins, as also the force and output of the

[1] Cf. "Vegetable Statics," Vol. I., p. 265.

left ventricle, acknowledging, however, previous work by Harvey, Lower, Borelli, Pitcairne, Keill and others. As became every physiologist of his time, he wrote on the "animal spirits" and on the "sympathy" between the nerves; he studied experimentally the physics of respiration; he produced pneumo-thorax in the dog, and speculated on the sources of animal heat, agreeing with Boerhaave and the iatro-physical school in attributing it to friction of the blood and blood-cells against the walls of the vessels. He tried to explain the florid nature of arterial blood, but on this point he was not so enlightened as his predecessor Lower about sixty years before. He used the microscope in an interesting way to try to gain information as to the cause of muscular contraction in the living frog. He incidentally saw the red blood corpuscles in the living capillaries and noticed that the diameter of the smallest vessel was equal to that of the blood-disc. He gives the receipt of an injection-fluid for blood-vessels. He continued Harvey's work, by studying the rupturing pressures in blood-vessels and the rupturing strain of various animal fibers. He speculated on the physiology of renal secretion.

In what would now be regarded as pure medicine and even surgery, Hales was just as active. He wrote critically on the therapeutic value of "tar-water"; he wrote on fevers and on the possible effects of fever heat on the blood, actually suggesting that the shivering fit of ague might be due to the too thick blood not passing with ease through the capillaries. He studied the effect of alcohol on the living organism by injecting brandy into the blood-vessels of the dog. He wrote on paracentesis abdominis. Hales spent a great deal of time in attempts to discover satisfactory solvents for stone in the bladder and the kidneys, and actually devised a method of extracting stone from the bladder.

In the physical sciences he wrote on earthquakes, and he invented an instrument for determining the depths of the ocean: this appears to have been of some practical service, but, according to one account, was lost in the West Indies. Hales invented a method for the dredging of harbors. He gives directions for "salting" meat for long voyages.

Hales, as we have seen, was patronized by Frederick, Prince of Wales, the eldest son of George II., who died before his father in 1751. His widow Augusta, daughter of Frederick, Duke of Saxe-Gotha, for the last ten years of Hales's life the Princess Dowager of Wales, had a great regard for the Reverend Doctor, and there is no doubt that had he so desired it, he might have become a bishop. The utmost he would allow, refusing a canonery of Windsor, was to be made "Clerk of the Closet" or almoner "to the Princess Dowager." After his death, the Princess erected a mural monument in marble to his memory in Westminster Abbey. He is not buried there amongst England's other great ones, but under the tower of his old church at Teddington. The memorial is wrought in *alto relievo;* it represents the figures of Religion

and Botany supporting a medallion of the philosopher beneath which is a globe with the winds portrayed on it in allusion to Hales's invention of ventilators. The laudatory inscription is in Latin verse, a translation of which I am enabled to give through the kindness of Professor Wallace Lindsay, LL.D., of the chair of Latin at the University of St. Andrews.

> To the Reverend Doctor Stephen Hales,
> Augusta, mother of good George III,
> Erected this monument.
> She selected him for her chaplin.
> He died, January 4th, 1761.
>
> At Hales' tomb which Augusta caused to rise with gleaming stone and to have due beauty, Piety and grey haired Faith and supreme Virtue, a sacred band, drop constant tears; while above the dead prophet divine Wisdom proclaims, "He was skilled in helping men's troubles, he too in tracing God's works. No lapse of time will weaken your praise, great Hales, or your titles! England is proud to enroll you amongst her noblest sons, England who can boast a Newton"!

This is interesting as being almost a contemporary estimate of Hales. His medical work and researches as a sanitarian are evidently alluded to in the phrase "helping men's troubles"; his more purely scientific work being alluded to in "tracing God's works." Sir James Edward Smith, the physician and naturalist, said "his philosophy was full of piety."

Seeing that the stone over the grave of Hales has done duty as one of the flag-stones of the porch of the old church of St. Mary's, Teddington, for more than 150 years, it is not surprising to find that its inscription is now almost entirely worn away. In January, 1911, a number of English botanists unveiled a tablet on the wall of the porch of the tower which they caused to be inscribed as follows:

> Beneath is the grave of Stephen Hales. The epitaph now partly obliterated but recovered from a record of 1795 is here inscribed by the piety of certain botanists A.D. 1911. "Here is interred the body of Stephen Hales, D.D. clerk of the closet to the Princess of Wales, who was minister of this parish 51 years. He died 14th of January, 1761, in the 84th year of his age."

One of the few redeeming features in the character of Frederick, Prince of Wales, was his friendship for Hales. It is not very far from where the Prince lived at Kew to where Hales worked at Teddington, and so H. R. H. would frequently drop in and watch the scientific clergyman surrounded by his pressure-gauges, bellows and crucibles.

Another, and much more distinguished neighbor of Hales, was the poet Pope with whom he seems to have been pretty intimate. Certain it is that the Reverend Doctor was one of the three witnesses to the will of the wicked wasp of Twickenham dated December 12, 1743.

Pope alludes to Hales as "plain Parson Hale" in the second of the moral essays (the poem is "Epistle II. To a lady: of the characters of women"). The lines are:

**Alas! I copy, or my draught would fail,**
**From honest Mahomet or plain Parson Hale.**

I confess I don't know what this means, but one can see a very unwarrantable liberty taken with Hales's name. The poet's own note on this is:

**Dr. Stephen Hale not more estimable for his useful discoveries as a natural philosopher than for his exemplary life and pastoral charity as a parish priest.**

Pope, however, has left it on record that he highly disapproved of the doctor's vivisectional experiments. Peg Woffington, the actress, was for a time a parishioner of Hales.

We strongly suspect that the theology of Hales was ponderous and his religious discourses dull. Absolutely correct as regards the sex morality of his own life, he appears to have dealt pretty severely with any erring members of his flock, for there is extant a list of names of women whom he made do public penance in church in a manner more resembling the custom amongst the strictest of the Scottish Covenanters than that of English Episcopalians.

At least one sermon that Hales delivered has come down to us, because it was published as the anniversary sermon preached before the Royal College of Physicians in the church of St. Mary-le-Bow on September 21, 1751. It is now a rare pamphlet, entitled "'The wisdom and goodness of God in the formation of man,' preached according to the institution of Dr. Crowne and his widow, the Lady Sadler, by Stephen Hales, D.D., F.R.S., Clerk of the Closet to Her Royal Highness the Princess of Wales." It is so full of curious anatomical and physiological allusions that it reads far more like a lecture in natural history than what we should consider a sermon. Another sermon preached by Hales in 1734 has come down to us. His text was Gal. VI., v. 2, the audience the trustees of the colony of Georgia, for Hales was one of the trustees of this newly founded colony (1733).

Another of Hales's neighbors was the dilettante, Horace Walpole, who lived near by at Strawberry Hill; he wrote cynically of Hales as a "poor, good, primitive creature." A far better judge, the physiologist Haller, declared that Hales was "pious, modest, indefatigable and born for the discovery of truth."

Hales must have been modest, for there are very few references to him in contemporary literature. He is not once mentioned in the chapter on Science in Ashton's "Social life in the reign of Queen Anne." By his scientific peers, however, his worth was fully recognized. In 1726 the University of Oxford conferred on him the degree of D.D. The Royal Academy of Sciences at Paris in 1753 elected Hales one of the eight foreign members in the room of Sir Hans Sloane, Bart: deceased.

The botanist, John Ellis, named a genus of plants, *Halesia,* in honor of him.

Hales's portrait was painted by Thomas Hudson (1701–1779), an English artist who had the honor to have Reynolds for a pupil. The monument in the Abbey is by Wilton who executed Wolfe's in the same sanctuary.

One of the most scholarly accounts of Hales is from the pen of Professor Percy M. Dawson, M.D.

To arrive at any definite ideas as regards Hales's views on his own times or on the society of his day is very difficult, since almost all that we know of him is in an exclusively scientific environment. Seeing that his patrons were the Prince and Princess of Wales and that he was quite intimate with the Duke of Cumberland, he could hardly have been other than an ardent Hanoverian. From all that we have to judge by, Hales's personal tastes harmonized with the Georgian Philistinism around him, for he is reported to have removed a beautiful east window in the church at Teddington, substituting for it something of greatly inferior beauty.

Hales lived through a period that was by no means destitute of incident; it included the Handel-Buononcini controversy, the Jacobite Rising, the quarrels of George II. with his eldest son, the battles of Dettingen and Fontenoy, the failure of the great attack on Carthagena (1741), the development of Britain's resources under the peaceful administration of Sir Robert Walpole, the commencement of the vigorous rule of William Pitt the elder, Wolfe's magnificent achievement on the Heights of Abraham, Clive's crushing of Surajah-Dowlah at Plassey, the reform of the calendar and the preaching of Wesley.

Pope, Gay, Young, Thomson, Cowper, Johnson, Gray and Collins in literature; Hogarth, Gainsborough and Sir Joshua in art, Handel in music, and Sir Hans Sloane in science are the names of honorable mention during the life-time of the Rev. Dr. Hales.

While we congratulate ourselves on having attained to an understanding of the principles of ventilation, on having abolished typhus fever from our hospitals, prisons and ships, on having devised apparatus for sustaining life in irrespirable and deadly atmospheres, let us never forget that the initial stages in the comprehension of these things were worked out not by any high-placed, well-paid, public official, but by a modest amateur, the scientifically minded, country clergyman, Stephen Hales.

# THE PLACE OF DESCRIPTION, DEFINITION AND CLASSIFICATION IN PHILOSOPHICAL BIOLOGY

By Professor WM. E. RITTER

SCRIPPS INSTITUTION FOR BIOLOGICAL RESEARCH

**Empirical theory of knowledge tends to regard detailed, complete description as identical with explanation. (Professor R. Adamson.)**

**. . . it would hardly be too much to define logic as the theory of classification. (W. S. Jevons.)**

**Science can extend only so far as the power of accurate classification extends. If we can not detect resemblances and assign their exact character and amount, we can not have that generalized knowledge which constitutes science. (W. S. Jevons.)**

**. . . the mathematical and mathematico-physical sciences have, in a great degree, determined men's views of the general nature and form of scientific truth; while natural history has not yet had time or opportunity to exert its due influence upon the current habits of philosophizing. (Wm. Whewell.)**

I WISH to point out in the briefest way possible the vital importance to biology of the truth of these statements.

We are familiar with the view that the transition from the pre-Darwinian to the Darwinian era of biology was accompanied by a complete revolution of conception as to the significance and value of our systems of classification of living beings. The current notion is that the old taxonomy was superficial in that it was merely descriptive, but that, with the oncoming of the doctrine of evolution, it became profound because it then became a record of evolution. While formerly we are wont to say, the schemes of classification were only logical, or verbal, those of the present era are truly scientific, because natural; and they are natural because based on genetic kindred. And in the minds of many biologists the still further notion has gained lodgment that systematic zoology and botany should be looked upon as marking the juvenile period in the life of biology; and as having been outgrown and left behind when evolution came, something as a boy's falsetto voice and beardless face are left behind when puberty is reached. It is this view, I suppose, which makes many a present-day biologist feel that if by chance he is caught having anything to do with description and classification, he must explain that it is only a little by-play with him, that he is not really interested in it, it being too small a matter to merit the full occupancy of his manly powers.

I want to show three things: first, exactly what has happened to taxonomy as biology has progressed; second, something of the monstrousness of the fallacy into which biologists have fallen in conceiving taxon-

omy as an outgrown stage in the development of biology; and third, something of the wretched consequences that have resulted from the fall.

A quotation from Huxley's "Life of Owen" may serve as a starting point of the discussion:

> **The classifications of the scientific taxonomist are of two kinds. Those of the one sort are merely handy reference catalogues. . . . The others, known as *natural* classifications, are arrangements of objects according to the sum total of their likenesses, in respect of certain characters. . . . And natural classification is of perennial importance, because the construction of it is the same thing as the accurate generalization of the facts of form, or the establishment of the empirical laws of the correlation of structure.**

That which makes taxonomic biology as practised by many systematists genuinely superficial, and has so depreciated its value in the minds of many biologists, is failure to distinguish sharply and see the profound significance of the difference between the two sorts of classification referred to by Huxley. The sort of classification which he calls "merely handy reference catalogues," I call *synoptic classification,* and remind the reader that such classification rests upon *synoptic description.* The other sort of classification, said by Huxley to be of "perennial importance, because the construction of it is the same thing as the accurate generalization of the facts of form," I call *analytic classification,* and ask the reader to note that it rests on *analytic description,* just as synoptic classification rests on synoptic description. And here I must state that analytic description and classification will include considerably more, as I use them, than was included by Huxley in his second sort of classification.

In order to bring into clearer view the close kindred between the biological and the logical aspects of our subject, we shall so choose our language as to fix attention quite as much on the *meaning of the names* used, as on the natural objects to which the names are applied.

If any one is disposed to shy at the proposal to thus connect biology with logic, he may be reminded of a dictum of one of the most famous and also the most objective of biologists—Cuvier. "In order to name well, you must know well," said the father of comparative anatomy. The import of this straightforward statement is that natural science deals with natural objects and that the names of these objects are the instruments by which the work is done. As a speculator, Cuvier did not escape the common weakness of the class, that of permitting Ideas to so intrude themselves between object and name as to prevent assurance that the two should really fit each other; but, as naturalist he stood firmly for the practise of making both knowing and naming apply very directly to the object. So far he was on the road to the sound position later definitely taken by J. S. Mill as a logician, that common sense is right in calling the word which stands for an object the name of the object, and not merely the name of our idea of the object.

Biology and logic, as understood in this discussion, have very much in common in that biology can do nothing with the natural objects which are its subject matter except through the instrumentality of a great lot of names; while logic can do nothing really significant with names of ideas concerning living beings unless those ideas have their exact counterparts in the objects themselves.

To be explicit, we shall deal with the description, definition and classification of *man;* but instead of doing this in the usual terminology of the systematist, we shall talk about the meaning of the word "man."

Imagine a normal child born on an oceanic island, the only animal inhabitants of which are its mother and itself; and imagine further that the mother, an educated woman, has taught her child all sorts of things, except about other human beings or other animals. Not the smallest fragment of information has she imparted to the child about its own kind, other than its mother. What would be the character of the child's knowledge of the humankind? Does any one question that it would be considerable, definite and real? Would not the child know its mother's form and countenance and voice, and many other things about her, just as well as though it knew innumerable other people? Unquestionably. It would have a descriptive, but no definitive knowledge of man, except in so far as the knowledge of itself would be differentiated from its knowledge of its mother.

Authorities on logic make a good deal of the point that "the concrete individual object can be described, but not defined." And they say, furthermore, that description is synonymous with "accidental definition," this latter being again defined as assigning the "accidents" of an individual. But since the "accidents" of an object have been, according to much historical logic, set over against its "essence," "accidents" have usually been treated by logic as a sort of Cinderella, the homely, despised sister, in the family of so-called Predicables.

I find justification for going thus much into logical doctrine in the fact that recent biology has shown a strong tendency to follow formal logic in exalting essence and despising accidents.

The practical point to be brought out is this: no matter how insignificant, or obscure, or transitory, may be a certain attribute of an object, in so far as that attribute is positively and repeatedly observed, it furnishes just as trustworthy a piece of knowledge about that object, as any attribute whatever can furnish.

Suppose the mother of our hypothetical island child had a mole on her chin; or that the sunshine brought out freckles on her nose which disappeared again during the winter. These marks would be accidents, according to logic; and biologically regarded would be quite insignificant. But they would be as indubitable elements in the child's knowledge of its mother as any other elements that can be mentioned.

Let me ask any reader who is "keen" enough on the different kinds of automobiles to be able to distinguish most of the "makes" as they are passed on the road, what marks he relies on for identifying each type of car? Is it not true that in most cases you depend upon one or a few very trivial things? Color comes in; but, on the whole, one finds himself giving less attention for identification purposes to this conspicuous attribute than to others far less conspicuous. Just now the shape and color, not the name, of the manufacturer's plate placed on the radiator of so many machines, is a good identification mark for machines coming toward one. For the rear view of a machine with the top up, the number and shape of the window panes in the back curtain are useful marks.

The purely logical points deserving emphasis in this familiar but typical case are: first, the trustworthiness of the identification marks in spite of their triviality. The number and shape of the windows in the back curtain are just as positive and real as traits, that is, they are, logically regarded, just as important attributes of a particular class of machines as the number and shape of the cylinders; and second, the fact that using the marks in the way we do is purely descriptive, so far as concerns the recognition of an individual machine, but is definitive in so far as that machine is differentiated from any other kind of machine. Had there never been more than one automobile made, so that then there could be no question of distinguishing it from others of its kind, the windows would still be no less positive and real, though they would not, manifestly, then furnish distinguishing traits within the general class automobiles. But here there comes to view a difference of the utmost importance between the way attributes are definitive of man-made objects like automobiles, and natural living objects like men. In the first class of objects we are perfectly sure that many, usually most, of the attributes which the old logic would call accidents had no genuinely dependent relation to most of the other attributes of the object; while in living beings, especially of the higher classes, we are now certain that the great majority, if not all, the attributes, even those which formal logic would call accidents, are in vital relation with many, usually very many, other attributes. Thus recurring to the shapes of back curtain windows in automobiles and freckles on the nose of our hypothetical island mother, we know that the former have no fundamental relation to the more essential attributes of the machines, as, for example, the style of engine or carburetor or magneto; while on the other hand we know with equal certainty that freckles are vitally related to, indeed are wholly dependent upon, various other attributes, notably the complex attribute known as complexion, which again is vitally related to the blood system, and so on.

There are few, if any, points at which biology is more at sea than

in this very matter of the factual and logical, *i. e.*, the objective and subjective relation of the attributes or traits of organisms to one another and to the whole.

We now return to the problem of defining the word man. By the time any normal child is four or five years old he is in possession of the raw materials of a fairly comprehensive and entirely reliable description, a less extensive, but still unequivocal, definition, and the first of the essentials of a classification of man. He positively knows some of the attributes which distinguish a man from a house or a rock; some of those which distinguish him from a tree; probably some of those which distinguish him from a fly; probably, too, some of those which distinguish him from a chicken; and almost certainly some of those which distinguish him from a dog, a cat, a cow, and a horse. In a word, he has the raw material for the synoptic description and classification of man; that is, for the synoptic meaning of the word man.

Attention should here be called to the fact that the synoptic classification of man as elementary biological instruction presents it is apt to be slighted at its two ends. Too frequently, the beginning is made with:

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| *Kingdom,* | *Animal,* and runs on: |
| Province, | Metazoa. |
| Phylum, | Vertebrata. |
| Class, | Mammalia. |
| Order, | Primates. |
| Genus, | Homo . . . and ends with |
| *Species,* | *Sapiens.* |

The point of criticism is that the super kingdom, the Empire (if our terminology must retain its ancient monarchic coloring), is not constantly enough included at the broad end; and at the narrow end the subspecies or variety is more frequently slighted than it ought to be; and from the very apex the individual is almost entirely ignored.

"*Empire,* Living Being, or Orgainsm, or Bios" ought to be always included as the logician's genus generalissimum; and, at the other end, "*Individual,* Eleanor, Ezra," etc., ought to be always included as the logician's species specialissima, or infirma species.

The synoptic description, definition and classification of man would then be: any natural body which is multicellular has a vertebral column, suckles its young, habitually walks erect on its hind limbs and uses its fore limbs for prehension, and talks rationally. And this is, too, both a biological and a logical meaning of the word man.

It is desirable to raise the question at this point as to the difference between the biological and the logical meaning of the term man. The kernel of the difference seems to me statable thus: The briefest possible biological meaning of the word spreads it out, as one might say, evenly over the whole living world, while the briefest possible

logical meaning does not do this. The insular mother whom we invoked in imagination may be supposed to teach her child formal logic, and, in so doing, to make use of herself and her child to illustrate the logician's use of the terms genus and species. She might say to the child:

> You and I are natural bodies like the rocks and the clouds; but since we talk with each other, a thing which neither rocks nor clouds can do, we are particular kinds of natural bodies. When bodies stand in such relation as this to one another, we, as logicians, speak of them as being in the relation of genus and species.

So far as I can see, this example, if supplemented by others of like import that might be drawn from inanimate nature, could be made to completely satisfy the needs of formal logic as touching its doctrines of naming, defining, dividing, classifying. In a word, formal logic is not obliged to take cognizance of the fact that living nature contains any organisms other than man himself. Logic is something that can be used upon living beings generally with great effect—something that can occupy itself very interestingly and profitably with such things, but it is not obliged to be so used.

Logic goes to nature to get illustrations of how thought works rather than to actually learn nature. Reverting to Jevons's statement that logic may be defined as the theory of classification, we may remark that, so far as external nature is concerned, while logic may be defined as the theory of classification, it can not be defined as the practise of classification. It is important to call attention to this distinction between logic and biology since even biologists frequently fail to recognize it and are beguiled into trying to impose the laws of thought upon nature by asserting that such and such a supposition about nature is a "logical necessity." Although logic is so important to the natural scientist as an instrument, quite as important is it never to forget that it is only an instrument. Logic is one of the many children of nature; it is not its parent or ruler.

A practical point to be noticed here is that right regard for logic in the business of the taxonomist clearly reveals both the unwarrantableness and misfortune of the view, so widely held, that synoptic descriptions and classifications are artificial or puerile, and devoid of scientific value. If such a definition of man as that just given does not express his nature—is not a natural definition—in what terms, pray, can he be naturally defined? The definition is natural, but meager. This and not its artificiality is its fault; and from this fault arises the need for the second kind of classification spoken of at the outset.

To this other sort of classification and the second meaning of the word man, we now turn. Logic lays great stress on the difference between extension and intension in the meaning of names. When the

word man is merely thought of as applying to the individuals of the human species, its meaning in extension is before us. When, on the other hand, thought goes to the attributes of man, to what makes him a man, rather than to individual men, it is occupied with the meaning in intension of the word.

Now, as to our point about the second, the analytic classification of man—the analytic meaning of the word man. Let us begin with the reminder that meaning in intension is concerned not with the mere naming of objects, but with the attributes of the objects named.

Let the reader recall that taxonomic research in both zoology and botany has for years, so far as it has been based on morphology exclusively, taken as one of its guiding principles *neglect nothing*. This means, stated in the terms of logic, that this aspect of taxonomy has incorporated into its purpose and method, the study of terms in their intension. This is really, I believe, what was in Huxley's mind, at least in the back-ground of it, when he asserted that the second kind of classification is the "same thing as the accurate generalization of the facts of form."

A prime object of this paper is to contend that biology has now reached a stage in its progress where we can no longer restrict our dictum "neglect nothing" to morphological attributes, but must extend it to all attributes of organisms whatever—morphological, physiological, ecological, chemical and all the rest. And it should be pointed out that the movement of biology in this direction was more or less distinctly seen by at least one biologist nearly a century ago, namely, G. R. Treviranus. "The doctrine of organization," he said, "is founded upon comparative anatomy, or the systematic distribution of living bodies, and on organic chemistry."

I believe a comprehensive review of the whole range of biological results won during the last five and twenty years, let us say, will convince any one that each of the main provinces of research—comparative physiology, ecology, experimental behavior, genetics and biochemistry, no less than histology, cytology, embryology and regeneration, would furnish differentia for a classification of the organisms used in the researches; or at least that they contain differentia corresponding to the systems of classification previously established on the basis of pure morphology.

What does this signify for the attitude of biologists toward their problems, and for methods and enterprises of research?

It signifies many things, one of which particularly concerns us now, and may be put into the following general proposition: No biological phenomenon is adequately interpreted or dealt with experimentally, until it has been considered with reference to the place which the organisms to which it pertains hold in the system of classification. To illus-

trate, no generalization about the chromosomal structure and behavior in the spermatogenesis of species *x* of genus *a* can be accepted as fully valid until compared with the chromosomal structure and behavior of species *M, N, O, P,* etc., of the same genus. And a like restriction must be placed on generalization about the reaction of species *x* to light, or to any other stimulus, or to its distribution in nature, and so on.

To undertake the recital of special researches in support of this proposition would be to undertake the review of most of the recent investigations in the provinces of biology mentioned. And notice this: The results of these researches look in the direction indicated despite the fact that in most cases the studies had little or no systematic intention. The great amount of evidence of this purport is mostly incidental to other motives of investigation.

I would not be understood as advancing the hypothesis that every species of plants and animals differs from every other species to some extent in every attribute. What I affirm is that the inductive evidence has now gone so far toward proving every sharply differentiated species to contain some differentia in all the main provinces of their structure and function, that to assume the absence of such differentia in any given case, is unwarranted.

Although in the interests of practical biology it is desirable that a searching examination of the whole range of biological knowledge should be made from the taxonomist's standpoint, for a short theoretical discussion like that in which we are now engaged all that is incumbent upon us is to look, and that only cursorily, into a single province of biology, namely, biochemistry. This is all that is necessary, I say, because the analysis of all phenomena of life into chemistry and physics being the ultimate goal of biology according to the now dominant biological philosophy, if it turns out that the chemical analysis is exhaustive only when done on the basis of taxonomy, then it would seem to follow necessarily that all phenomena of structure and function intervening between the grosser morphological features with which taxonomy has for the most part busied itself, and the ultimate physicochemical features, must also be brought to a taxonomic basis before they are exhaustive.

It would be difficult to find a better example of weightiness of inductive evidence as dependent upon cumulation in particular lines, and convergence of different lines, than that presented by biochemistry bearing on the hypothesis here under consideration. Concerning the evidence of the chemical differentiation of species drawn from investigations on the blood of higher animals, recall the results of Reichart and Brown on the crystallization of hemoglobin. Here is one of their statements:

> Each form, *a*-oxyhemoglobin, *b*-oxyhemoglobin, etc., appears always in its own proper form and axial ratio when the blood of different individuals of the same species is examined. . . . But upon comparing the corresponding substances in different species of a genus, it is generally found that they differ one from the other to a greater or less degree; the differences being such that when complete crystallographic data are at hand the species can be distinguished by these differences in their hemoglobins.

Let us assume there is ground for questioning the full trustworthiness of this conclusion. Notice the strong presumption of its general reliability produced by its accordance with evidence from a wholly different kind of research on the serum of blood, namely, that on the precipitin reaction; and from still another kind, namely, that on the hemolytic action of one blood upon another. Nor should we fail to recognize the convergence of evidence for chemical specificity of organisms drawn from comparative investigation on milk; on the enzymes of digestion; and from such direct analyses of organic structure as those of the sperm of many species and genera of fishes. I mention only one other line of evidence of like purport clearly to be counted as chemical, though not usually so cited; namely, that of the odors and flavors of plants and animals. This is an exceedingly rich field of inquiry, even though difficult of cultivation by ordinary laboratory methods. The methods to be chiefly relied upon here are those of the senses of smell and taste, and it is interesting to reflect that there is available for utilization not merely these senses in man, but in animals as well. In the olfactory sense of the ant and the scent hunting dog, for example, we have a method of chemical discrimination—of qualitative chemical analysis if you please—which seems to surpass in delicacy anything laboratory manipulation can hope to attain.

Natural history and biochemistry are being inevitably drawn together by the very nature of their subject matter. Descriptive zoology and botany are becoming chemical in part, and bio-chemistry is becoming zoological and botanical in part. Organisms are indeed being "reduced to chemistry" in the familiar phrase; but the statement tells only half the story, unless it specifies the *particular* chemistry to which they are reduced. Each kind of organism has a chemistry to some extent unique. In one of its aspects biochemistry is becoming a subdivision, or branch, of systematic zoology and botany, just as anatomy has been for a long time. "Almost any group of tissues," said Minot, "would offer a favorable opportunity for the discussion of genetic classification." Seemingly the same may be said of biochemical substances.

Many biologists working in several provinces of the organic realm, particularly in those which, like cytology and biochemistry are concerned with the minute and difficultly observed structure and functions of organisms, appear to be laboring under the delusion that they are doing something totally different from description. They seem to think their work

apart from and exalted above description if they can apply the terms analysis, or especially causal analysis, to it. As though the treatment of causal factors which are intrinsic in an organism were not part of the description of that organism, and as though causal factors extrinsic to the organism; that is, belonging to the organism's environment, were essentially a part of biology at all! I believe full and unbiased consideration will convince any one that the word analysis, occurring so frequently in recent biological writings, always means *analytic description and classification,* as these terms are elucidated above, if it has any objective meaning at all. It is undoubtedly true that as touching organisms themselves a vast amount of analysis has been practised upon them that is not descriptive; but this is because it is purely speculative—because it is subjective and not objective. Most of the analysis of the characters of adult organisms into "determinants," "determiners," "factors," etc., of the germ, is of this sort. And as touching the environments of organisms it is a remarkable thing once one comes to notice it duly that the results of innumerable researches have been published in biological journals during the last two or three decades, that were not in a strict sense biological. The studies were undertaken not so much to learn the nature of organisms as to test the properties of certain physical and chemical agents in respect to their influence on organisms. Incidentally, one might almost say, they have brought out many suggestive facts about how organisms may behave when placed under unusual and unnatural conditions. But they have not taught us so very much about the normal behavior of normal organisms under normal conditions. Indeed, a considerable number of biologists have been so bewildered by what they have seen and by their mode of speculating, that they have seriously questioned whether there is such a thing as a normal organism in a normal environment!

The sooner it is borne in upon the minds of all students of living beings, no matter with what aspects of such beings they may be occupied, that they are engaged in the great task of describing and classifying the living world; and, so far as "pure biology" is concerned, are doing nothing else, the sooner will objective biology get itself set off from subjective biology and the sooner will philosophical biology become purged of the many morbific growths which now impair its health and mar its beauty. Never more than in this present day when experimental research has gained so wide and lasting, and, on the whole, beneficent a hold in biology, has there been need of fidelity to description and classification. Never more than now, I say, because the practical work of experimentation on organisms does not promote observance of the classifier's watchword neglect nothing. Indeed, when the experimental method is raised, as some enthusiasts try to raise it, to the high place of an end in itself, the tendency is rather to neglect everything except

the one or a very few things which the experimenter must of necessity make the object of each special piece of work.

Although the practical biologist knows that his strivings after explanation are utterly futile unless always accompanied by description the spell of subjectivistic metaphysics is still so strong over science that not many biologists have yet grasped the fact that all true explanation is reached through description. Investigators rarely seem to notice that the explanations they propose are usually in reality hypotheses, and that the proof, or the greater or less probability of truth of these explanations (hypotheses) are wholly dependent upon the accuracy and fullness of description to which the organisms are subjected in the aspects of them to which the explanations pertain. Take the classic case of Goethe's explanation of the flower as a transformed branch with its leaves. Is it not true that just in so far as this explanation is accepted it is done on the basis of the accepted descriptions of flowers and branches and leaves? If a true explanation of cancer is ever reached does any one fail to recognize, when he thinks about the matter, that it must come in the form of well-verified description and classification of the whole complex of organic phenomena implicated in the disease?

A true though incomplete distinction between description in the ordinary sense and explanation in the ordinary sense is that the process of describing is very little guided by hypothesis, while explaining is very largely so guided.

Early in the paper, I promised to say something about the baneful effects that have flowed from the neglect by modern biology of the principles of description and classification. *Sine systeme chaos,* is the motto standing at the head of an elaborate, recently published work on the arrangement of the animal kingdom. This motto should be adopted, in substance at least, for any and every comprehensive biological treatise, no matter in what field; and I insist that failure to adopt it has thrown the speculative biology of our time into a literal state of chaos.

The revolt against the dry and formal nomenclatorialism into which biology had wandered in the period immediately preceding Darwin, has gone so far as practically to deny that many of the really best established, most important names in biology have any essential meaning at all. Witness, for example, the effort now taking shape with a few biologists, notably with J. S. Haldane, "to raise the term organism to the level of a category," as Henderson has characterized Haldane's undertaking. As a matter of fact, the effort is to restore, not to originally elevate the term, for a study of the history of biological theory clearly discloses that the term organism was long ago accepted as a category in the very best writings. For example, whenever the cell is interpreted as an "elementary *organism,*" as it has usually been since Brücke first

conceived it thus, organism is acknowledged to be a "category"—a real entity—of biology.

From the extreme devotion to description and classification which characterized the older biology, the new has gone, in several of its most important aspects, to the opposite extreme of scarcely any accurate description and classification at all. Very few biologists appear to have considered how this attitude toward systematization has affected philosophical biology, and especially the biology of man, and so the general theories of human life, and influence upon human conduct.

We approach here a matter of vast scope, one altogether too vast to be more than touched in a communication like this. But there is one segment of it which, though lying close to the field of biology proper and of great importance, appears to have attracted the attention of professional biologists but little.

I refer to that melange (the thing will not allow itself to be called a system) of utterances and more or less definite teachings about the human species that has got into men's minds during the last thirty or forty years, and has found its fullest expression in the writings of Friedrich Nietzsche.

Surely biologists have not taken as much note as they should of the insistence by philosophical anarchists and other disciples of Nietzsche that their prophet is the particular and supreme "philosopher of evolution."

Into the tumultuous whirlpool of discussion of the Nietzschean doctrines I have no wish to enter, at least in this place; but a few things about it I believe ought to receive consideration by biologists, especially by American biologists. Should the matter be thus attended to, I believe it will be seen that there is a great measure of truth in the claim for Nietzsche as the philosopher of evolution; evolution being conceived as it usually has been in the modern period; and the particular point I want to make is that he did his philosophizing, primarily about man and very secondarily about the rest of the living world, in all but total disregard of, seemingly in almost total ignorance of, the natural history aspect of biology. His appeals to physiology, or something he called physiology; and to some of the results and conceptions of physiological psychology (although I do not recall his having used exactly this phrase) were constant and often very telling. But his neglect of, yes, more than that, his positive antipathy for the systematic, the coordinational, the interdependent aspects of living nature are striking indeed, once one comes to study his works with the point definitely in mind. I have searched, vainly, both in his own writings and in those of several professed followers of his, for evidence that the conceptions organism and "organic" with the meaning these terms have to every genuine natural history biologist, enter in any definite and positive fashion into his

philosophy. And here is the point that ought to arrest the attention of scientific men, indeed of all thoughtful persons. So far as concerns this vital matter the Nietzschean school is in strict accord with the "habits of philosophying," as Whewell calls it, now dominant in biology.

Listen to this, one of Nietzsche's "Apophthegms and Darts" occurring in the "Twilight of the Idols":

> I mistrust all systematisers and avoid them. The will to system is a lack of rectitude.

What a familiar sound this has to those who, from being at home in the discussions of recent speculative biology, have had dinned in their ears the doctrine that systematic zoology and botany are old-fashioned, childish and insignificant! Of course any one even moderately acquainted with Nietzsche's writings knows that what he was aiming at primarily in inveighing against systems was the systems of traditional philosophy. And undoubtedly, as Mügge remarks: "many have been drawn to him for this very reason." Presumably most persons, be they scientists or philosophers, or be they admirers or detestors of Nietzsche, would easily and willingly recognize that he knew little and cared less about the systems of natural history. They would go further and say that that fact had no essential relation to his antipathies against systems of philosophy. And this brings us back to the main point—the point to which, according to my view, men neither of science nor of philosophy have given sufficient attention, namely, that the system, the orderliness which every educated person now knows to be so greatly characteristic of living nature, must enter fundamentally into any philosophy of man and the animate world generally in order that that philosophy may be even approximately true and in any way adequate.

The following quotation from "Beyond Good and Evil" will open the way to a perception of the kindred between Neitzscheism and modern theoretical biology. He says:

> Let me be pardoned as an old philologist who can not desist from the mischief of putting his finger on bad modes of interpretation, but "Nature's conformity to law," of which you physicists talk so proudly as though—why it exists only owing to your interpretation and bad "philology." It is no matter of fact, no "text" but rather just a naïvely humanitarian adjustment and perversion of meaning, with which you make abundant concessions to the democratic instincts of the modern soul.

The items in this which specially concern us are the references to nature and democracy. Nietzsche appears to have felt as genuinely and deeply as any modern whatever the importance of "return to nature" —a cry which, though hackneyed, he was willing to adopt. For this feeling he is entitled, as an esthetic philosopher, to great credit. The keenness of perception and vigor of expression with which he protests against the repudiation of external nature, the vilification of the human body,

and the distrust of the senses as these abominations have manifested themselves in the great systems of historical philosophy from the later Greek period, on through the heyday of Christian theology, down into the modern era of German subjectivism, deserve the careful and sympathetic regard of every man of science. The best of his utterances under this head which I have found are contained in "Beyond Good and Evil," and "The Twilight of the Idols." The chapter on "Prejudices of Philosophers" in the first mentioned, and the sections, "The Problem of Socrates," "Reason in Philosophy," and "Morality as Anti-naturalness" deserve special mention.

The disastrous mistake made by Nietzsche and into which his disciples have followed him, was in believing that he *actually did* "return to nature." As a matter of fact he never came any nearer nature than did J. J. Rousseau, who raised such a hullabaloo a century and a half ago over the same subject, and for whom Nietzsche professed such an ardent hatred. It is easy for a student of real nature to understand why Nietzsche hated Rousseau more spleenishly, if such a thing were possible, then he hated people generally. Probably it was because he vaguely realized that he was doing just what Rousseau tried to do, *i. e., make* of nature what he would like to have it; and then saw that what Rousseau wanted nature to be was almost the antithesis of what he himself wanted it to be. While Rousseau wanted nature to be peaceful, gentle, benevolent and all that, and so easily found enough in it to make himself believe it to be essentially of this sort, Nietzsche as easily found enough in it to convince him that in its fundamentals nature is of the sort he liked; that is, selfish and powerful and hard and cruel.

Biologists ought to examine right carefully Nietzsche's famous doctrine of "Will to Power." His effort to make this a universal and all-sufficing principle of living nature had its strict counterpart, if not, indeed, its inspiration and model, in struggle survivalism of the Weismannian type. And the doctrine has degenerated into a sort of fiendish crotchet with many of Nietzsche's disciples, much as strugglism has with many biologists. And the reasoning, if reasoning it can justly be called, is much the same by the two sets of persons. "Wherever I found living matter," said Nietzsche, "I found will to power, and even in the servant I found the yearning to be master." (Thus spake Zarathustra.) As an illustration take an alligator, a great hunk of "living matter," sunning itself on a sand bank for hours at a time without so much as flopping its tail. What a striking case of willing to power! And what determination of a servant to be a master! Or if Nietzsche by chance ever looked through a microscope at the slow come-and-go of protoplasm confined within the cell membrane in a hair of a spider-lily, what a convincing proof of "will to power" and "desire for mastery" he had before him!

And one finds illustrations and arguments quite as convincing almost

every time he consults any orthodox Selectionist. For instance, such a biologist will watch with you a hornbill, a bird the size of a hen with a bill as large as the horn of a two-year-old bull, as the creature strives to get its bill out of its way so it can see its food, and then displays its ingenuity in getting the food far enough back in its immobile, bony mouth to enable it to swallow the morsel, and will explain to you without a smile how this bird and its ancestors have been able to survive in the struggle for existence because of the masterful bill! Or, coming down to pure and overwhelming logic, such a biologist will affirm (still without a smile) that you are bound to accept his explanation of the hornbill's bill unless you have some better explanation to offer! And he will go yet further (still in dead earnest) and tell you *he* and not you, must be the judge of which explanation is better. A very rudimentary sense of humor is another and by no means an unimportant trait-in-common between Nietzscheans and the dominant school of speculative biologists.

But that in particular which ought to make these biologists join with the disciples of Nietzsche in proclaiming their prophet the supreme philosopher of evolution is intimated in the above quotation,

> Nature's conformity to law is no matter of fact . . . but rather just a naïvely humanitarian adjustment and perversion of meaning with which you make abundant concessions to the democratic instincts of the modern soul.

The tap-root of the life philosophy of both groups is the dogma that the gross, easily seen living things about us everywhere and all the time are "mere outward expressions" of an Essence, deep, invisible, intangible, a comprehension of the working of which and the control of which is the goal of all life science.

To be sure, the fact that temperamentally Nietzsche was highly artistic and very little scientific made him interpret and evaluate human life in terms very different from those used by the biologists when they treat of man. But the close kindred between "Nietzsche's cloud-like visions of Eternal Recurrence and Superman" and the nebulous hereditary substance, germ plasm, and "The Fit" of most biological eugenists should not be overlooked by anybody interested in problems of human welfare. Nietzsche's followers have not been slow to see the meaning of the man-breeding proposals of our day. Müggе says:

> In Galton's Eugenics, founded upon the idea of evolution and the assumption that the human will is in some small measure capable of guiding the course of evolution, we see a scientific realization of Nietzsche's dreams.

And let no one, especially in this democratic country of ours, neglect to mark well the character of those dreams: Aristocracy carried through to its logical end. The best shall rule and "by means of force." The best shall be masters; the commonalty their slaves, literally and not figuratively. The only law shall be the law of the strong, the fit.

Those eugenists whose biological philosophy rests on germ-plasmic

fatalism, appear not to have recognized—probably because the goal is so far away—that they face toward an aristocracy most hateful to one who knows what democracy really means. Here again Nietzsche was more far-sighted than his biological counterparts, for he clearly saw and loudly proclaimed that supermen must be a very few very select masters with the great common "herd" their slaves.

And so our discussion turns back to its beginning. The laws of interdependence, of reciprocal connection and action which seem to pervade all living nature and bind it into a great, infinitely complex unity are only a seeming, only an outward manifestation of the ultimate Reality, so the dominating biologists accord with Nietzscheans in declaring. The "web of life" of which the ordinary man recognizes himself to be a part and which vulgar natural history strives to accurately describe and define and to naturally classify, is of little profit or interest because unreal or at best semi-real, say οἱ ἄριστοι the aristocracy of modern biology.

We may hope a generation of students of nature will arise after a while, a majority of whom will genuinely believe and act in accordance with their faith, that common sense has a real part in the interpretation of nature. And when such biologists come and succeed in making themselves heard and felt there may be ushered in an era of rule of the best who will be indeed best because they will rule according to the law of the whole and not by the law of some Being above or beneath or somewhere else outside of nature, whether called superman or the fit, or by some other name.

It is high time that natural history should "exert its due influence upon the current habits of philosophizing."

# EUGENICS

By FRANZ BOAS

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THE possibility of raising the standards of human physique and mentality by judicious means has been preached for years by the apostles of eugenics, and has taken hold of the public mind to such an extent that eugenic measures have even found a place on the statute books of a number of states, and that the public conscience disapproves of marriages that are thought bound to produce unhealthy offspring.

The thought that it may be possible by these means to eliminate suffering and to strive for higher ideals is a beautiful one, and makes a strong appeal to those who have at heart the advance of humanity. Our experiences in stock and plant breeding have shown that it is feasible, by appropriate selection, to improve the breed in almost any direction that we may choose: in size, form, color; and even in physiological functions, as in the rapidity of development, in fertility or mentality. It is, therefore, more than probable that similar results may be obtained in man by careful mating of appropriately selected individuals—provided that man allows himself to be selected in the same manner as we select animals. We have also the right to assume that, by preventing the propagation of mentally or physically inferior strains, the gross average standing of a population may be raised.

Although these methods sound attractive, there are serious limitations to their applicability. It is obvious, from a purely biological point of view, that only those features that are hereditary can be affected by eugenic selection. If an individual possesses a desirable quality the development of which is wholly due to environmental causes, and that will not be repeated in the descendants, its selection will have no influence upon the following generations. It is, therefore, of fundamental importance to know what is hereditary and what not. We all know that features or color of hair and skin are hereditary; in other words, that in these respects children resemble organically their parents, no matter in what environment they may have been brought up. In other cases, however, the determining influence of heredity is not so clear. We know that stature depends upon hereditary causes, but that it is also greatly influenced by more or less favorable conditions during the period of growth. We know that rapidity of development is no less influenced by these two causes, and that, in general, the more subject

an anatomical or physiological trait is to the influence of environment, the less definitely can we speak of a controlling influence of heredity, and the less are we justified in claiming that nature, not nurture, is the deciding element. It would seem, therefore, that the first duty of the eugenist should be to determine empirically and without bias what features are hereditary and what not.

Unfortunately this has not been the method pursued; but the battle-cry of the eugenists, "Nature not nurture," has been raised to the rank of a dogma, and the environmental conditions that make and unmake man, physically and mentally, have been relegated to the background.

It is easy to see that in many cases environmental causes may convey the erroneous impression of hereditary phenomena. We know that poor people develop slowly and remain short of stature as compared to wealthy people. We may find, therefore, in a poor area, apparently a low hereditary stature, that, however, would change if the economic life of the people were changed. We may find proportions of the body determined by occupations, and apparently transmitted from father to son, provided both father and son follow the same occupation. It is obvious that the more far-reaching the environmental influences are that act upon successive generations, the more readily will a false impression of heredity be given.

Here we reach a parting of the ways of the biological eugenist and the student of human society. Most modern biologists are so entirely dominated by the notion that function depends upon form, that they seek for an anatomical basis for all differences of function. To give an instance: they are inclined to assume that higher civilization is due to a higher type; that better health depends upon a better hereditary stock; and so on. The anthropologist, on the other hand, is convinced that many different anatomical forms can be adapted to the same social functions; and he ascribes, therefore, greater weight to the functions, and believes that in many cases differences of form may be adaptations to different functions. He believes that different types of man may reach the same civilization, that better health may be produced by better bringing up of any of the existing types of man. The anatomical differences to which the biologist reduces social phenomena are hereditary; the environmental causes which the anthropologist sees reflected in human form are individually acquired, and not transmitted by heredity. It would lead us too far to prove the correctness of the anthropologist's view. It must suffice to point out a very few examples. Sameness of language acquired under the same linguistic environment by members of the most diverse human types, sameness of food selected from among the products of nature by people belonging to the same cultural area, similarity of movements required in industrial pursuits, the habits of sedentary or nomadic life, all of which are distributed

without any reference to physical type, will illustrate that there is ample evidence showing the lack of relation between social habits and physical type.

The serious demand must, therefore, be made that eugenists cease to look at the forms, functions, and activities of man from the dogmatic point of view according to which each feature is assumed to be hereditary, but that they begin to examine them from a more critical point of view, requiring that in each and every case the hereditary character of a trait must be established before it can be assumed to exist.

The question at issue is well illustrated by the extended statistics of cacogenics, of the histories of defective families. Setting aside for a moment cases of hereditary pathological conditions, we find that alcoholism and criminality are particularly ascribed to hereditary causes. When we study the family histories in question, we can see often, that, if the individuals had been protected by favorable home surroundings and by possession of adequate means of support against the abuse of alcohol or other drugs as well as against criminality, they would not have fallen victims to their alleged hereditary tendencies, any more than many a weakling who is brought up under favorable circumstances. Their resistance to the temptations of their environment would have entitled them to be classed as moral heroes. The scales applied to the criminal family and to the well-to-do are clearly quite distinct; and, so far as heredity is concerned, no more follows from the collected data of delinquency than would follow from the fact that in an agricultural community the occupation of farming descends from father to son.

Whether or not constitutional debility based on hereditary causes may also be proved in these cases, is a question by itself that deserves attention; but neither can it be considered as proved, nor do we grant that the selection of delinquents would eliminate all those who possess equal constitutional debility.

Basing our views on the observed fact, that the most diverse types of man may adapt themselves to the same forms of life, I claim that, unless the contrary can be proved, we must assume that all complex activities are socially determined, and not hereditary; that a change in social conditions will change the whole character of social activities without influencing in the least the hereditary characteristics of the individuals concerned. Therefore, when the attempt is made to prove that defects or points of excellence are hereditary, it is essential that all possibility of a purely environmentally or socially determined repetition of ancestral traits be excluded.

If this rigidity of proof is insisted on, it will appear that many of the data on which the theory of eugenics is based are unsatisfactory, and that much greater care must be exerted than finds favor with the enthusiastic adherents of eugenic theories.

All this does not contradict the fact that individual physical and mental characteristics are hereditary, and that, by proper selection from among the large series of varying individual forms that occur among all types of people, certain strains might be selected that have admirable qualities, while others might be suppressed that are not so favored.

It is claimed that the practical application has become a necessity because among all civilized nations there is a marked tendency to general degeneration. I do not believe that this assertion has been adequately proved. In modern society the conditions of life have become markedly varied as compared with those of former periods. While some groups live under most favorable conditions, that require active use of body and mind, others live in abject poverty, and their activities have more than ever before been degraded to those of machines. At the same time, the variety of human activities is much greater than it used to be. It is, therefore, quite intelligible that the functional activities of each nation must show an increased degree of differentiation, a higher degree of variability. Even if the general average of the mental and physical types of the people has remained the same, there must be a larger number now than formerly who fall below a certain given low standard, while there must also be more than formerly who exceed a given high standard. The number of defectives can be counted by statistics of poor relief, delinquency and insanity, but there is no way of determining the increase of those individuals who are raised above the norm of a higher standard. Therefore they escape our notice. It may, therefore, very well be that the number of defectives increases, without, however, influencing the value of a population as a whole, because it is merely an expression of an increased degree of variability.

Added to this is the fact that, arbitrarily selected, absolute standards do not retain their significance. Even if no change in the absolute standard should be made, the degree of physical and mental energy required to keep one's self under modern conditions above a certain minimum of achievement is greater than it used to be. This is due to the greater complexity of our life and to the increasing number of competing individuals. Greater capacity is required to attain a high degree of prominence than was needed in other periods of our history. The claim that we have to contend against national degeneracy must, therefore, be better substantiated than it is now.

This problem is further complicated by the advances of public hygiene, which have had the result of lowering infant mortality, and thus have brought about a change in the composition of the population, in so far as many who would have succumbed to deleterious conditions in early years enter into the adult population and must have an influence upon the general distribution of vitality.

There is still another important aspect of eugenics that should

make us pause before we accept this new ambitious theory as a panacea for human ills. The radical eugenist treats the problem of procreation from a purely rationalistic point of view, and assumes that the ideal of human development lies in the complete rationalization of human life. As a matter of fact, the conclusions to be drawn from the study of the customs and habits of mankind show that such an ideal is unattainable, and more particularly that the emotions clustering about procreation belong to those that are most deeply seated in the human soul, and that are ineradicable.

Here again the anthropologist and the biologist are at odds. The natural sciences do not recognize in their scheme a valuation of the phenomena of nature, nor do they count emotions as moving forces: they endeavor to reduce all happenings to the actions of physical causes. Reason alone reigns in their domain. For this reason the scientist likes to look at mental life from the same rational standpoint, and sees as the goal of human development an era of reason, as opposed to the former periods of unhealthy fantastic emotion.

The anthropologist, on the other hand, can not acknowledge such a complete domination of emotion by reason. He rather sees the steady advance of the rational knowledge of mankind, which is a source of satisfaction to him no less than to the biologist; but he sees also that mankind does not put this knowledge to purely reasonable use, but that its actions are swayed by emotions no less now than in former times, although the increase of knowledge limits the extreme forms of unreasonable emotional activities. Religion and political life, and our everyday habits, present endless proofs of the fact that our actions are the results of emotional preferences, that conform in a general way to our rational knowledge, but which are not determined by reason; that we rather try to justify our choice of action by reason than have our actions dictated by reason.

It is, therefore, exceedingly unlikely that a rational control of one of the strongest passions of man could ever succeed. If even in matters of minor importance evasion of the law is of common occurrence, this would be infinitely more common in questions that touch our inner life so deeply. The instinctive repugnance against eugenic legislation is based on this feeling.

It can not be doubted that the enforcement of eugenic legislation would have a far-reaching effect upon social life, and that it would tend to raise the standard of certain selected hereditary strains. It is, however, an open question what would happen to the selected strains owing to the changed social ideals; and it is inexcusable to refuse to consider those fundamental changes that would certainly be connected with eugenic practice, and to confine ourselves to the biological effect that may be wrought, for we know that in the great mass of a healthy

population the social stimulus is infinitely more potent than the biological mechanism.

Although we are ignorant of the results of a rigid application of eugenics, a few of its results may be foretold with great certainty.

The eugenist who tries more than to eliminate the unfit will first of all be called upon to answer the question what strains are the best to cultivate. If it is a question of breeding Indian corn or chickens, we know what we want. We desire a large yield of good corn, or many eggs of heavy weight. But what do we want in man? Is it physical excellence, mental ability, creative power, or artistic genius? We must select certain ideals that we want to raise. Considering then the fundamental differences in ideals of distinct types of civilization, have we a right to give to our modern ideals the stamp of finality, and suppress what does not fit into our life? There is little doubt that we, at the present time, give much less weight to beauty than to logic. Shall we then try to raise a generation of logical thinkers, suppress those whose emotional life is vigorous, and try to bring it about that reason shall reign supreme, and that human activities shall be performed with clock-like precision? The precise cultural forms that would develop can, of course, not be foretold, because they are culturally, not biologically, determined; but there is little doubt that within certain limits the intensity of emotional life—regardless of its form—and the vigor of logical thought—regardless of its contents—could be increased or decreased by organic selection. Such a deliberate selection of qualities which would modify the character of nations implies an overestimation of the standards that we have reached, which to my mind appears intolerable. Personally the logical thinker may be most congenial to me, nevertheless I respect the sacred ideals of the dreamer who lives in a world of musical tones, and whose creative power is to me a marvel that surpasses understanding.

Without a selection of standards, eugenic practise is impossible; but if we read the history of mankind aright, we ought to hesitate before we try to set our standards for all time to come, for they are only one phase in the development of mankind.

This consideration applies only to our right to apply creative eugenic principles, not to the question whether practical results by eugenic selection can be attained. I have pointed out before how much in this respect is still hypothetical, or at least of doubtful value, because the social factors outweigh the biological ones.

At the present time the idea of creating the best human types by selective mating is hardly a practical one, because it dwells only as a desirable ideal in the minds of some enthusiasts.

The immediate application of eugenics is rather concerned with the elimination of strains that are a burden to the nation or to themselves,

and to raise the standard of humanity by the suppression of the progeny of the defective classes. I am doubtful whether eugenics alone will have material results in this direction, for, in view of the fundamental influence of environmental causes, that I set forth before, it is perfectly safe to say that no amount of eugenic selection will overcome those social conditions by means of which we have raised a poverty and disease-stricken proletariat, which will be reborn from even the best stock, so long as the social conditions persist that remorselessly push human beings into helpless and hopeless misery. The effect would probably be to push new groups of individuals into the deadly environment where they would take the place of the eliminated defectives. Eugenics alone can not solve the problem. It requires much more an amelioration of the social conditions of the poor which would also raise many of the apparently defective to higher levels.

Another aspect of the problem is of much more vital importance to mankind. The object of eugenics is the raising of a better race and to do away with increasing suffering by eliminating those who are by heredity destined to suffer and to cause suffering. The humanitarian idea of the conquest of suffering, and the ideal of raising human efficiency to heights never before reached, make eugenics particularly attractive.

I believe that the human mind and body are so constituted that the attainment of these ends would lead to the destruction of society. The wish for the elimination of unnecessary suffering is divided by a narrow margin from the wish for the elimination of all suffering. While, humanely speaking, this may be a beautiful ideal, it is unattainable. The performance of the labors of mankind and the conflict of duties will always be accompanied by suffering that must be borne, and that men must be willing to bear. Many of the works of sublime beauty are the precious fruit of mental agony; and we should be poor, indeed, if the willingness of man to suffer should disappear. However, if we cultivate this ideal, then that which was discomfort yesterday will be suffering to-day, and the elimination of discomforts will lead to an effeminacy that must be disastrous to the race.

This effect is further emphasized by the increasing demands for self-perfection. The more complex our civilization and the more extended our technical skill and our knowledge, the more energy is demanded for reaching the highest efficiency, and the less is it admissible that the working capacity of the individual should be diminished by suffering. We are clearly drifting towards that danger-line where the individual will no longer bear discomfort or pain for the sake of the continuance of the race, and where our emotional life is so strongly repressed by the desire for self-perfection—or by self-indulgence—that the coming generation is sacrificed to the selfishness of the living. The phenome-

non that characterized the end of antiquity, when no children were found to take the place of the passing generations, is being repeated; and the more vigorously the eugenic ideals of the elimination of suffering and of self-development are held up, the sooner shall we drift towards the destruction of the race.

Eugenics should, therefore, not be allowed to deceive us into the belief that we should try to raise a race of supermen, nor that it should be our aim to eliminate all suffering and pain. The attempt to suppress those defective classes whose deficiencies can be proved by rigid methods to be due to hereditary causes, and to prevent unions that will unavoidably lead to the birth of disease-stricken progeny, is the proper field of eugenics. How much can be and should be attempted in this field depends upon the results of careful studies of the law of heredity. Eugenics is not a panacea that will cure human ills, it is rather a dangerous sword that may turn its edge against those who rely on its strength.

# THE PSYCHOLOGY OF WISH FULFILMENT

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"IF wishes were horses beggars would ride" is a nursery saw which, in the light of recent developments in psychology, has come to have a much more universal application than it was formerly supposed to have. If the followers of the Freudian school of psychologists can be believed—and there are many reasons for believing them—all of us, no matter how apparently contented we are and how well we are supplied with the good things of the earth, are "beggars," because at one time or another and in one way or another we are daily betraying the presence of unfulfilled wishes. Many of these wishes are of such a character that we ourselves can not put them into words. Indeed if they were put into words for us we should straightway deny that such a wish is or was ever harbored by us in our waking moments. But the stretch of time indicated by "waking moments" is only a minor part of the twenty-four hours. Even during the time we are not asleep we are often abstracted, day-dreaming, letting moments go by in reverie. Only during a limited part of our waking moments are we keenly and alertly "all there" in the possession of our faculties. There are thus, even apart from sleep, many unguarded moments when these so-called "repressed wishes" may show themselves.

In waking moments we wish only for the conventional things which will not run counter to our social traditions or code of living. But these open and above-board wishes are not very interesting to the psychologist. Since they are harmless and call for the kinds of things that everybody in our circle wishes for, we do not mind admitting them and talking about them. Open and uncensored wishes are best seen in children (though children at an early age begin to show repressions). Only to-night I heard a little girl of nine say: "I wish I were a boy and were sixteen years old—I'd marry Ann" (her nine-year old companion). And recently I heard a boy of eight say to his father: "I wish you would go away forever; then I could marry mother." The spontaneous and uncensored wishes of children gradually disappear as the children take on the speech conventions of the adult. But even though the crassness of the form of expression of the wish disappears with age, there is no reason to suppose that the human organism ever gets to the point where wishes just as unconventional as the above do not rise to trouble it. Such wishes, though, are immediately repressed; we never harbor them nor do we express them clearly to ourselves in our waking moments.

The steps by which repression takes place in the simpler cases are not especially difficult to understand. When the child wants something it ought not to have, its mother hands it something else and moves the object about until the child reaches out for it. When the adult strives for something which society denies him, his environment offers him, if he is normal, something which is "almost as good," although it may not wholly take the place of the thing he originally strove for. This in general is the process of substitution or sublimation. It is never complete from the first moment of childhood. Consequently it is natural to suppose that many of the things which have been denied us should at times beckon to us. But since they are *banned* they must beckon in devious ways. These sometime grim specters both of the present and of the past can not break through the barriers of our staid and sober waking moments, so they exhibit themselves, at least to the *initiated,* in shadowy form in reverie, and in more substantial form in the slips we make in conversation and in writing, and in the things we laugh at; but clearest of all in dreams. I say the meaning is clear to the initiated because it does require special training and experience to analyze these seemingly nonsensical slips of tongue and pen, these highly elaborated and apparently meaningless dreams, into the *wishes* (instinct and habit impulses) which gave them birth. It is fortunate for us that we are protected in this way from having to face openly many of our own wishes and the wishes of our friends.

A few years ago when this doctrine was first advanced by Sigmund Freud, the noted psycho-pathologist at Vienna, it raised a storm of opposition, not only from the staid, home-loving, every-day men and women, but from scientific men as well (objection to the view seems to stand in almost direct ratio to the amount of repression the individual possesses). The truth of the matter is that Freud wrote mainly for his medical colleagues, but his words were taken up and bandied about by the press and by men who had not seriously studied them. This unjust treatment of Freud led a few physicians in this country, who had had personal contact with him, to champion his cause and to go so far as to say that they alone, with Freud, knew how to interpret dreams. Freudianism thus became a kind of cult, and the only devotees allowed openly to worship at the shrine were those who had had personal training under Freud. Fortunately science is objective, and whatever good there is in one man's work can usually be verified, although in the process of verification modifications are usually made which lead gradually to a satisfactory working basis. This belief in the objective nature of science has led many psychologists in this country who have not been fortunate enough to have personal contact with Freud to try out his methods and to attempt to verify his findings for themselves. They can do this without necessarily putting themselves on record as being

interpreters of Freud. The psychologist's interest in this movement lies in its possible usefulness in analyzing character. The analysis of personal character, like the analysis of emotions, has always resisted the efforts of the psychological laboratories. I believe all psychologists will agree with me when I say that no laboratory-developed test has ever enabled us to tell whether a man is at heart a liar, a profligate, or a coveter of his neighbor's wife.

### Suppressed Wishes expressed in the Slips of Every-day Life

In social gatherings where there is some slight emotional strain and the customary control over speech is off, we find numberless examples of the expression of the suppressed wish. If we were to make a tabulation of such slips met with in a single week, the list would be long. Most of the slips reveal too much to be put down in print. But I can mention some of the types usually met with.

An elderly bachelor, the friend of the family, squires his friend's wife to a dance. He introduces her as "Mrs. S." (giving her maiden name instead of her married name, "Mrs. J."). If taxed with possessing the wish that the woman were single so that he might have another chance, he would indignantly deny that any such thought had ever crossed his mind. This is probably true in the sense that had any such wish crossed his mind in his ordinary waking moments it would have been put down immediately—repressed. It is rather interesting to note in the above case, which is an actual one, that later in the evening the "Mrs. J." referred to, after having danced with a man other than her escort, shortly afterwards introduced her partner as "Mr. J." (her husband)! It is of course unusual to find material so readily as this. I noted another and common type of slip the same day as the above. A woman of my acquaintance had to go to the New York Central Station to meet three girl friends *en route* from Boston to Washington. She decided to buy some flowers for each of them. I went to the florist shop with her and to my surprise she purchased only two bouquets, saying: "*A* likes violets, but *B* is fond of orchids." When we reached the sidewalk I asked her why she disliked "*C*" so much. "Why do you think I dislike her?" she asked. "Because," I said, "you have done all in your power to annihilate her—you have forgotten to purchase any flowers for her." She showed confusion but gracefully admitted that I had saved her from making a serious *faux pas*. To take revenge, however, she gave me my just deserts by saying: "I can't bear to be around a man who has your view of life." (She afterwards admitted, however, that "*C*" had been for many years a thorn in the flesh.)

Slips are often expressive of wishes which bear on the pleasanter side of life. I mislay my cane and umbrella, both of which I prize

highly, and find that I left them at the house of a friend where I last had dinner and a game of bridge. The wish shortly to visit so pleasant a place again is very clearly implied. To take a single final example in this connection: Only a moment ago it was necessary for me to call a man on the telephone. I said: "This is Dr. John B. Watson, of the Johns Hopkins Hospital," instead of Johns Hopkins University. One skilled in analysis could easily read in this slight slip the wish that I had gone into medicine instead of into psychology (even this analysis, though, would be far from complete).

Slips of the pen are just as numerous and just as interesting revealers of hidden character as are slips in speech. It is in dreams, however, that we get our most interesting and valuable material for analysis.

### The Dream as a Vehicle of Wish Fulfilment

According to the now generally accepted viewpoint we dream almost constantly. If we were to put the question: "Do you often dream?" to a group of men, women and children, the answers would be various. Most of the men would say: "I seldom dream, and when I do my dreams are meaningless and uninteresting." Some of the women would say that they often have wonderful and thrilling dreams while others would maintain that their dreams were few and had no interest. The children would tell us that they dreamed frequently and that their dreams were always interesting and exciting. It is difficult to convince most adults that if they do not dream constantly they do dream much more frequently than they are at present aware of. Even my own students are at first sceptical about the universality of the dream processes. I ask them to try hard to recall their dreams on waking in the morning, and if they awake in the night to jot down a sentence or two of their dreams so that they can recall the whole dream on awaking in the morning. In a short time most of them are convinced that they do dream almost constantly.

If it is difficult to convince one that he dreams constantly, it is a Herculean task to convince him of the second step in understanding dreams—to wit, that his dreams are *not* at bottom bizarre and meaningless, but, on the contrary, that they are orderly, logical, and, if we know the history of the individual, almost predictable. We must admit immediately that if we take the dream at its face value, that is, read the words that the dreamer puts down as a true report of his dream, it is a creature of fancy in the wildest sense of that word. We get the reports in bits with no apparent connecting links. Fanciful words are put in. Names are mentioned which are the names of no individuals known to the dreamer. Places are visited which have never been visited by the dreamer. (Yet in almost every dream the starting point is some

incident—situation, person, place, or thing—met with by the dreamer at some time not twenty-four hours before the dream took place.)

We get our clue to the dream as being a wish fulfilment by taking the dreams of children. Their dreams are as uncensored as is their conversation. Before Christmas my own children dreamed nightly that they had received the things they wanted for Christmas. The dreams were clear, logical and open wishes. Why should the dreams of adults be less logical and less open unless they are to act as concealers of the wish? If the dream processes in the child run in an orderly and logical way, would it indeed not be curious to find the dream processes of the adult less logical and full of meaning?

This argument gives us good *a priori* grounds for supposing that the dreams of adults too are full of meaning and are logical; that there is a wish in every dream and that the wish is fulfilled in the dream. The reason dreams appear illogical is due to the fact that if the wish were to be expressed in its logical form it would not square with our every-day habits of thought and action. We should be disinclined to admit even to ourselves that we have such dreams. Immediately upon waking only so much of the dream is remembered, that is, put into ordinary speech, as will square with our life at the time. The dream is "censored," in other words.

The question immediately arises who is the censor or what part of us does the censoring? The Freudians have made more or less of a "metaphysical entity" out of the censor. They suppose that when wishes are repressed they are repressed into the "unconscious," and that this mysterious censor stands at the trapdoor lying between the conscious and the unconscious. Many of us do not believe in a world of the unconscious (a few of us even have grave doubts about the usefulness of the term consciousness), hence we try to explain censorship along ordinary biological lines. We believe that one group of habits can "down" another group of habits—or instincts. In this case our ordinary system of habits—those which we call expressive of our "real selves"—inhibit or quench (keep inactive or partially inactive) those habits and instinctive tendencies which belong largely in the past.

This conception of the dream as having both censored and uncensored features has led us to divide the dream into its specious or manifest content (face value, which is usually nonsensical) and its latent or logical content. We should say that while the manifest content of the dream is nonsensical, its true or latent content is usually logical and expressive of some wish that has been suppressed in the waking state.

On examination the manifest content of dreams is found to be full of symbols. As long as the dream does not have to be put into customary language, it is allowed to stand as it is dreamed—the sym-

bolic features are uncensored. Symbolism is much more common than is ordinarily supposed. All early language was symbolic. The language of children and of savages abounds in symbolism. Symbolic modes of expression both in art and in literature are among the earliest forms of treating difficult situations in delicate and inoffensive ways. In other words, symbols in art are a necessity and serve the same purpose as does the censor in the dreams. Even those of us who have not an artistic education, however, have become familiar with the commoner forms of symbolism through our acquaintance with literature. In the dream, when the more finely controlled physiological processes are in abeyance, there is a tendency to revert to the symbolic modes of expression. This has its use, because on awaking the dream does not shock us, since we make no attempt to analyze or trace back in the dream the symbol's original meaning. Hence we find that the manifest content is often filled with symbols which occasionally give us the clue to the dream analysis.

The dream then brings surcease from our maladjustments: If we are denied power, influence, or love by society or by individuals, we can obtain these desiderata in our dreams. We can possess in dreams the things which we can not have by day. In sleep the poor man becomes a Midas, the ugly woman handsome, the childless woman surrounded by children, and those who in daily life live upon a crust, in their dreams dine like princes (after living upon canned goods for two months in the Dry Tortugas, the burden of my every dream was food). Where the wished-for things are compatible with our daily code, they are remembered on awaking as they were dreamed. Society, however, will not allow the unmarried woman to have children, however keen her desire for them. Hence her dreams in which the wish is gratified are remembered in meaningless words and symbols.

## Biological Basis of the Wish

Long before the time Freud's doctrine saw the light of day, William James gave the key to what I believed to be the true explanation of the wish. Thirty years ago he wrote:

> . . . I am often confronted by the necessity of standing by one of my selves and relinquishing the rest. Not that I would not, if I could, be both handsome and fat and well dressed, and a great athlete, and make a million a year, be a wit, a *bon-vivant*, and a lady-killer, as well as a philosopher; a philanthropist, a statesman, a warrior, and African explorer, as well as a "tone-poet" and a saint. But the thing is simply impossible. The millionaire's work would run counter to the saint's; the *bon-vivant* and the philanthropist would trip each other up; the philosopher and the lady-killer could not well keep house in the same tenement of clay. Such different characters may conceivably at the outset of life be alike *possible* to a man. But to make any one of them actual, the rest must more or less be suppressed.

What James is particularly emphasizing here is that the human organism is instinctively capable of developing along many different lines, but that due to the stress of civilization some of these instinctive capacities must be thwarted. In addition to these impulses which are instinctive, and therefore hereditary, there are many habit impulses which are equally strong and which for similar reasons must be given up. The systems of habits we form (*i. e.*, the acts we learn to perform) at four years of age will not serve us when we are twelve, and those formed at the age of twelve will not serve us when we become adults. As we pass from childhood to man's estate, we are constantly having to give up thousands of activities which our nervous and muscular systems have a tendency to perform. Some of these instinctive tendencies born with use are poor heritages; some of the habits we early develop are equally poor possessions. But, whether they are "good" or "bad," they must give way as we put on the habits required of adults. Some of them yield with difficulty and we often get badly twisted in attempting to put them away, as every psychiatric clinic can testify. It is among these frustrated impulses that I would find the biological basis of the unfulfilled wish. Such "wishes" need never have been "conscious" and *need never have been suppressed into Freud's realm of the unconscious.* It may be inferred from this that there is no particular reason for applying the term "wish" to such tendencies. What we discover then in dreams and in conversational slips and other lapses are really at heart "reaction tendencies"—tendencies which we need never have faced nor put into words at any time. On Freud's theory these "wishes" have at one time been faced and put into words by the individual, and when faced they were recognized as not squaring with his ethical code. They were then immediately "repressed into the unconscious."

A few illustrations may help in understanding how thwarted tendencies may lay the basis for the so-called unfulfilled wish which later appears in the dream. One individual becomes a psychologist in spite of his strong interest in becoming a medical man, because at the time it was easier for him to get the training along psychological lines. Another pursues a business career—when, if he had had his choice, he would have become a writer of plays. Sometimes on account of the care of a mother or of younger brothers and sisters, a young man can not marry, even though the mating instinct is normal; such a course of action necessarily leaves any unfulfilled wishes and frustrated impulses in its train. Again a young man will marry and settle down when mature consideration would show that his career would advance much more rapidly if he were not burdened with a family. Again, an individual marries, and without even admitting to himself that his marriage is a failure, he gradually shuts himself off from any emo-

tional expression—protects himself from the married state by sublimating his natural domestic ties; usually in some kind of engrossing work, but often in questionable ways—by hobbies, speed manias and excesses of various kinds. In connection with this it is interesting to note that the automobile, quite apart from its utilitarian value, is coming to be a widely used means of repression or wish sublimation. I have been struck by the enormously increasing number of women drivers. Women in the present state of society have not the same access to absorbing kinds of work that men have (which will shortly come to be realized as a crime far worse than that of the Inquisition). Hence their chances of normal sublimation are limited. For this reason women seek an outlet by rushing to the war as nurses, in becoming social workers, pursuing aviation, etc. Now if I am right in this analysis these unexercised tendencies to do things other than we are doing are never quite got rid of. We can not get rid of them unless we could build ourselves over again so that our organic machinery would work only along certain lines and only for certain occupations. Since we can not completely live these tendencies down we are all more or less "unadjusted" and ill adapted. These maladjustments are exhibited whenever the brakes are off, that is, whenever our higher and well-developed habits of speech and action are dormant, as in sleep, in emotional disturbances, etc.

Many but not all of these "wishes" can be traced to early childhood or to adolescence, which is a time of stress and strain and a period of great excitement. In childhood the boy often puts himself in his father's place; he wishes that he were grown like his father and could take his father's place, for then his mother would notice him more and he would not have to feel the weight of authority. The girl likewise often becomes closely attached to her father and wishes her mother would die (which in childhood means to disappear or go away) so that she could be all in all to her father. These wishes, from the standpoint of popular morality, are perfectly innocent; but as the children grow older they are told that such wishes are wrong and that they should not speak in such a "dreadful" way. Such wishes are, then, gradually suppressed, replaced by some other mode of expression. But the replacement is often imperfect. The apostle's saying "When we become men we put away childish things" was written before the days of psycho-analysis. We do not put them away—we replace them, but they never for us completely lose their impulsive power. Parents who show excessive emotional reactions towards their children—overmuch fondling of them—often encourage these wishes. The children take on more and more the wished-for forms of attachment. Later on in life such wishes may show themselves in dreams and occasionally in more objective ways. Now and then we find a young man whose mother has long since

died who can find little attraction in the girls with whom he associates. He is totally unaware of the cause of this apathy and would probably be the first one to scoff at the true explanation. In a similar way adults may become too much attached to children. This is often seen in the case of a woman whose husband has died leaving her with an only son. The son becomes substituted for the father, and her reactions which she looks upon as those belonging merely to a devoted mother, soon take on certain characteristics of those she would show to her husband. (The mother usually objects to the marriage of the son—on the grounds usually that the girl is not "suited to him.") Again from a moral point of view, as we ordinarily understand the term, her actions are exemplary. When I have expressed these views I have been often indignantly asked if parents should not caress their children. Of course I answer "yes"; but certainly if Freud has taught us anything, it is to give heed to our relations with our children. Overindulgence in caresses is far worse for their future happiness and poise than is overindulgence in material things.

The analysis of dreams is a field which belongs to the specially qualified physician—the psycho-analyst. It sometimes takes weeks, months and even years, to give genuine analysis of a dream. Special psycho-analytic methods are necessary to the unraveling of dreams, as well as special skill in handling the subject. Hence the dream will probably never mean any more to the ordinary individual than it does to-day. The crass analyses of friends and neighbors are worthless, nor should one be disturbed over a dream because someone has told him that Freud would say such and such things about it.

Dream analysis when made by experts has been of almost unbelievable service in treating the functional nervous diseases (neurasthenia, psychasthenia, hysteria, etc.). The dreams of such patients reveal their past in sections: the physician gradually joins these sections and can tell the patient where the trouble lies (that is, tell him the wishes around which all his dreams revolve). Knowing the cause of his distress, the patient, assisted by the physician, can form *new sets of habits which do not conflict.* Cures are thus effected without the use of drugs. The cures, however, smack not at all of the mysterious.

I have already expressed the wish that technical psycho-analysis may lead finally over into genuine character analysis. Many men high up in the business world, the diplomatic service, and in government positions generally, often have enormous responsibilities put upon them—there are times in the lives of such men when they are put under terrific strain from the outside: such men should be relatively free from strong inward conflicts and repressions. It seems fantastic to say that such persons ought to be selected only after careful psycho-analysis, but the whole essence of the psycho-analytic movement strongly suggests such a procedure.

# WAR AND THE SURVIVAL OF THE FITTEST

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"THE survival of the fittest" is a phrase coined by Herbert Spencer and first used by him in his "Principles of Biology,"[1] published in 1864. By this phrase he sought to express in purely mechanical terms the operation of nature in the evolution of organisms, a process which Darwin had called "natural selection or the preservation of favored races in the struggle for life." Alfred Russel Wallace, who shares with Darwin the honor of discovering the principle of natural selection, recognized at once the advantages of Spencer's phrase and wrote to Darwin urging its acceptance as a substitute for "natural selection." He said:

> It is a plain expression of the fact, while natural selection is a metaphorical expression of it and to a certain degree incorrect, since . . . nature does not so much select special varieties as exterminate the most unfavorable ones.

But Darwin, while perceiving the advantages of the phrase and admitting its greater accuracy, pointed out the objection that it can not be used as a substantive governing a verb. He also regards the bringing into connection of natural and artificial selection by the term "natural selection" as an advantage not to be overlooked, and the wide use of the term both at home and abroad made him doubtful whether it could be given up. "With all its faults," he said, "I should be sorry to see the attempt made." In the later editions of the "Origin of Species," Darwin used "survival of the fittest" as an alternative of "natural selection"; and Spencer in his subsequent writings used both phrases with something like equal frequency.[2]

"The survival of the fittest," then, and "natural selection" are two expressions for practically the same thing, namely, the mode of descent of organisms and groups of organisms from earlier and simpler forms. This mode briefly stated is as follows: The conditions of life necessitate on the part of all living things a struggle for existence, and this struggle is intensified by the procreative powers of animals and plants, more being brought into existence than can possibly survive; in all organisms there is a tendency to vary and in the struggle the organisms which

[1] Spencer, Herbert, "Principles of Biology," Vol. I., p. 530. Revised and enlarged edition, New York, 1898.

[2] See "Life and Letters of Charles Darwin," II., pp. 229–30, N. Y., 1901.

happen to be better fitted to their environment than others, because of some favorable variation, possess on that account an advantage which enables them to live and reproduce their kind while those not so favored are eliminated; this favorable variation reappears in the progeny of those that survive, by virtue of the tendency of like to produce like, and thus each succeeding generation becomes more closely adapted to the special circumstances of its life, and there is a gradual change of the species in the direction of better and better adaptation to these circumstances.

Assuming, then, the primordial existence of organisms with a tendency to vary, we have in "natural selection" or "the survival of the fittest" an explanation of how all living creatures (and the explanation holds for societies as well) have come to be what they are, in so far, at least, as their development has not been directly and consciously affected by human effort. It is not the entire explanation, to be sure. Darwin himself did not regard it as such. "I am convinced," he said, "that natural selection has been the most important, but not the exclusive, means of modification."[3] But, so far as it goes, it may be accepted as a true account of how evolution has taken place. "Natural selection" or "the survival of the fittest" is a law of nature.

Now what is the significance of this law of nature with respect to the possibility and desirability of eliminating the curse of war? Some declare that such elimination is undesirable because, as they believe, it is by war that social progress has been achieved; and impossible, also, because war, they assert, is a manifestation of a fixed and unchanging biological and social law. And so we find in current discussions of war frequent reference to "the inviolable laws of nature," and this particular biological and social law of the survival of the fittest is adduced oftimes as a bar to the promotion of peace. It is brought forward with the idea, apparently, that it gives a peculiarly scientific and conclusive aspect to all arguments against the efforts and hopes of the advocates of peace. To expect or desire the cessation of war, we are told, is to disregard the law of the survival of the fittest, and the natural means of social advancement; it is Utopian, and Utopian is, with many, merely a polite substitute for chimerical, vagarious or nonsensical. Let us see whether this law has really anything to do with the possibility of eliminating war.

Since the promulgation of the evolutionary philosophy the doctrine of the survival of the fittest has been most frequently proclaimed in justification of the present competitive system of industry. Competition, it is said, is a law of nature, and the sole motive to human effort, though how a law may become a motive is never clearly explained.

[3] "Origin of Species," sixth London edition, p. 5.

The stock presentation of the case is well illustrated by the following from an editorial in the Saturday *Evening Post:*

> Competition—the struggle to the death for life and hope—is not, in most of its outer manifestations, a pretty thing. If any man had invented it he would have got hard words from the Utopian, but it happens to have been invented by the Creator of All Things and to be the motive power in evolutionary advancement from the first Protozoan to Shakespeare.

It would be hard to find in equal space a more fallacious collocation of ideas. Competition is not necessarily "a struggle to the death"; hope is not its object; to proclaim it as an invention of the Creator is merely an appeal to religious prejudice, and it has not been the motive power in evolutionary advancement "from the first Protozoan to Shakespeare." It would be easy to show directly the fallacies of such reasoning. They will appear, however, in the course of this discussion if it be kept in mind that war is itself a form of competition. Anything applicable to the one subject is therefore applicable to the other.[4] We shall confine our attention here to the law of the survival of the fittest as it relates to the subject of war.

For an illustration of the current teachings concerning the necessity of war as evidenced by the biological law of evolution, we turn to Bernhardi's book on "Germany and the Next War." It offers by no means the only example of such teachings; current articles in English and American periodicals on the nature of war and the necessity of preparedness would serve our purpose quite as well; but it happens to be at hand and all we need is a definite and formal statement of the doctrines to be discussed. Says Bernhardi:

> War is a biological necessity of the first importance, a regulative element in the life of mankind which can not be dispensed with since without it an unhealthy development will follow, which excludes every advancement of the race, and therefore all real civilization. "War is the father of all things." The sages of antiquity long before Darwin recognized this.

He quotes with approval the following from Claus Wagner's "Der Krieg als schaffendes Weltprinzip":

> The natural law, to which all laws of Nature can be reduced, is the law of struggle. All intrasocial property, all thoughts, inventions, and institutions, as indeed, the social system itself, are a result of the intrasocial struggle, in which one survives and another is cast out. The extrasocial, the supersocial, struggle which guides the external development of societies, nations and races, is war. The internal development, the intrasocial struggle, is man's daily work—the struggle of thoughts, feelings, wishes, sciences, activities. The outward development, the supersocial struggle, is the sanguinary struggle of nations—war.

[4] See Howerth, I. W., "Work and Life," Chap. V., New York, 1912, for an extended discussion of competition, natural and industrial.

Again, he says,

> Struggle is, therefore, a universal law of nature, and the instinct of self-preservation which leads to struggle is acknowledged to be a natural condition of existence.

He concludes that war is an unqualified necessity, justifiable from every point of view, and that

> the efforts directed towards the abolition of war must not only be termed foolish, but absolutely immoral, and must be stigmatized as unworthy of the human race. . . . The whole idea represents a presumptuous encroachment on the natural laws of development which can only lead to the most disastrous consequences for humanity generally.

We purpose to show that these arguments, if arguments they may be called, betray a gross misconception of "nature," "biological necessity" and "the law of struggle." If sufficiently clear, and if attended to, the demonstration should carry the conviction that the shallowness and ignorance implied by such teachings are equaled only by their obvious viciousness. Let us begin by analyzing the struggle for existence in order to see whether the universality of this struggle is proof of the impossibility of abolishing war.

When we analyze the struggle for existence, as carried on either by biological organisms or by nations, we find that it involves not only a competitive struggle of organism against organism or nation against nation, but also a struggle against natural conditions. In so far as it is a struggle against nature, it has nothing to do with war; it would remain if war were eliminated. Moreover international competition manifests itself not only in war, but also in commerce, art, science, etc. Only rarely does it degenerate into war. War, then, is only a part of the struggle for existence. It is merely a phase of this struggle. Its elimination would not in the least interfere with the great law of struggle. If the nations of the world should become Christian, in fact as well as in name, and the principles of love and brotherhood should prevail throughout the world, there would still be plenty of opportunity for struggle afforded by nature, and by human nature, and progress need not be delayed. The law of progress is action, and action need not be of the destructive nature of war.

What are we to say, then, of this doctrine that the supersocial struggle for existence is the sanguinary struggle of nations—of the doctrine "that war is as necessary as the struggle of the elements in nature"?[3] What reply are we to make to the contention that bloodletting is necessary to the virility of nations; that international conflict is to be looked upon as a means of salvation from the degenerating in-

[3] Quoted by Bernhardi, from A. W. von Schelegel.

fluences of "slothful ease"; that the "strenuous life," militarism being often implied if not expressed by that phrase, is the highest manifestation of the true grandeur of man and of nations? Merely this, that it mistakes the necessity of social action for the necessity of a particular kind of action, that is, war, and betrays a misconception of the laws of evolution or a painful indifference to the social consequences of the epigrammatical expression of half-truths. Action is a necessity both of individual and of social life. We must act if we would live, and it is commendable to rouse nations to intelligent action, but it does not follow from this that nations are under the inevitable necessity of making war upon one another. We Americans, for instance, must manifest activity or we shall stagnate, but we need not on that account intervene in Mexico or provoke war with the Japanese. We have enough to do at home to evoke all the activity and all the intelligence of which we are capable. There are, and will always be, problems of production, distribution, education, sanitation. Concerted action in swatting the fly or killing mosquitoes, to say nothing of organized action to redeem our arid lands, to reforest our devastated hills, and to harvest the riches of mountains and plains, affords ample opportunity for the exercise of all our energies, are in reality far more dignified occupations than the destruction of property and life in war, and the glory to be won therefrom will eclipse the showy nonsense of war if society ever awakens from its present illusion. The struggle for existence, we repeat, does not necessarily involve war. Man can be strenuous without being destructive.

But, while war is only an incident in the struggle for existence and might therefore be eliminated without serious interference with that struggle, yet, on the whole and in general, it results in the survival of the fittest. Is this not a sufficient reason why it should not be abolished, even if it were possible for society to do so? Would not continuous peace among nations necessitate the abrogation of the law of the survival of the fittest and defeat the progress which is achieved by such survival? Let us consider this question squarely on its merits. We shall see that the fact that war does admittedly result in the survival of the fittest is no reason whatever why war should be condoned or encouraged.

First, let us observe that evolution is not necessarily progressive, that it may lead to degradation, as in the case of the parasite, as well as to the development of a paragon of strength and beauty. The downfall of the Roman Empire was as much a phenomenon of social evolution as the rise of the Dutch republic. In the evolutionary process the survivors are indeed the fittest, but the fittest are not necessarily the best; they are not always better from an ethical standpoint than those whom they supplant; they are merely those who are best adapted to the prevailing conditions. Of course no one who really understands the doctrine of evolution needs instruction on this point. Spencer long ago

pointed out "that the fittest throughout a wide range of cases—perhaps the widest range—are not "the best."[6] Professor Huxley is quite as explicit on this point. In a well-known passage he says:

> There is another fallacy which appears to me to pervade the so-called "ethics of evolution." It is the notion that because, on the whole, animals and plants have advanced in perfection of organization by means of the struggle for existence and the consequent "survival of the fittest"; therefore men in society, men as ethical beings, must look to the same process to help them towards perfection. I suspect that this fallacy has arisen out of the unfortunate ambiguity of the phrase "survival of the fittest," "Fittest" has a connotation of "best"; and about "best" there hangs a moral flavor. In cosmic nature, however, what is "fittest" depends upon the conditions. Long since, I ventured to point out that if our hemisphere were to cool again, the survival of the fittest might bring about, in the vegetable kingdom, a population of more and more stunted and humbler and humbler organisms, until the "fittest" that survived might be nothing but lichens, diatoms, and such microscopic organisms as those which give red snow its color; while, if it became hotter the pleasant valleys of the Thames and the Isis might be uninhabitable by any animated beings save those that flourish in a tropical jungle. They, as the fittest, the best adapted to the changed conditions, would survive.[7]

Since the survival of the fittest does not necessarily result in progress, what becomes of the argument that war is essential to progress because it results in the survival of the fittest? Plainly it is unfounded. As a matter of fact this "law of nature" has no more bearing upon the wisdom or expediency of striving to abolish war than the law of gravitation has upon the possibility of success in aviation.

The idea then that war is "a moral obligation" because it results in the survival of the fittest is as unwarranted as the inference from the law of the struggle for existence that it is a "biological necessity." Hence the related idea that it is impossible and undesirable to abolish war betrays a very imperfect conception of the laws of biology and of social advancement.

The prevalent notion with regard to the survival of the fittest is belied by the commonest experiences of life. In wild life, among animals, for instance, the fittest are determined usually though not always by battle, but under domestication the fittest are determined by the application of intelligent tests. No precedent stockman would encourage battle among his flocks and herds in order to determine the fittest. He would not even look with indifference upon such a battle, or with the optimistic hope that "somehow good will be the final goal of ill." He would see at once not only its waste, but also, the improbability of his deriving anything but accidental good from

[6] See Spencer, H., "Mr. Martineau on Evolution," Essays, Vol. I., p. 379, N. Y., 1910.

[7] Huxley, "Evolution and Ethics and other Essays," pp. 80–1.

such a battle. No man really believes in reliance upon the natural law of the survival of the fittest to bring about, without direction, results in which he is immediately and personally interested. Certainly those who talk about the necessity of war and assert their belief in the natural law of the survival of the fittest do not act upon this belief in matters of personal concern. Would such persons, if a child of theirs were in battle with a ferocious animal, stand quietly by and console themselves with the reflection that the fittest will survive? Would they, if engaged in agriculture, carefully prepare the ground, sow the seed, and after the germination of the crop leave the plants to struggle with the weeds in order that the fittest might survive? Certainly not! No more should the world expect continuous progress as a result of war.

We have now seen that war is not an essential part of the struggle for existence, and that, while it results in the survival of the fittest, it does not necessarily result in progress, the reason being that the fittest are not necessarily the best. It remains to show that the whole case for war rests upon a profound misconception of the nature and significance of natural law. It will appear that the law of the survival of the fittest, instead of being an obstacle in the way of the achievement of continuous peace, is the condition that makes such achievement a possibility. First, let us consider the question: What is a law of nature?

If we think of the world in terms of the philosophy of idealism, it is a world consisting wholly in sense-impressions. Says Pearson:

> These sense-impressions appear to follow an unchanging routine capable of expression in the brief formulæ of science because the perceptive and reflective faculties are machines of practically the same type in all normal human beings.[8]

From this view a natural law is merely a brief description of the recognized sequence of sense-impressions. If, on the other hand, we regard the world as what it seems to be, namely, a collection or aggregation of material phenomena, then a natural law is merely a statement of the coexistence and sequence of such phenomena. In neither case is a law of nature what many appear to suppose it to be, that is, an expression of the will of a superior authority commanding obedience. It is a wholly mistaken idea that the laws of nature are commands, and that they are to be discovered in order to be obeyed. I suspect this idea lies at the bottom of the consciousness of those who claim that the survival of the fittest is an effective bar to the promotion of peace. They think of a natural law as in the nature of a command, and not, as it really is, a mere formula for expressing uniformity in the action of some natural force or forces so long as the conditions are the same. A natural law is not a prescription, but a description; we owe it no allegiance; the

[8] Pearson, K., "Grammar of Science," London, 1895, p. 132.

object of discovery is not obedience, but control. Every natural law that is ascertained gives us additional power over nature, inasmuch as it reveals the conditions necessary to the intelligent control of the forces of nature and to the progressive achievement of its conquest. This point is well illustrated by the progress and practical value of natural science. Why does science endeavor to achieve the discovery of natural laws in the physical world? Is it that we may regard ourselves as impotent in the presence of such laws? or that we may yield obedience to them to avoid punishment? or that we may stand aloof and allow the free and unrestricted operation of the physical forces of nature? or that we may talk learnedly of these laws as insuperable obstacles to improvement upon nature by the practical application of our intelligence? Certainly not! It is for the practical purpose of enabling man to direct the forces of nature, and for that alone. Knowledge is power. Newton's discovery of the law of gravitation has not discouraged the construction of sky-scrapers. It has merely shown the necessity of care that in such construction the center of gravity fall within the base. Instead of an obstacle to architectural achievement, the law of gravity, representing as it does the unfailing operation of a natural force, indicates the very condition of success.

The case is not different when we pass from the physical to the biological or social world. Those who think that a biological or social law of nature presents opposition to intelligent efforts to bring about biological or social progress have only to consider the daily action of man for a conclusive confutation of their view. We may take an example from the field of agriculture.

It is a well-known fact that Indian corn (*Zea Mays*) is descended from a grass not now found in a wild state, but undoubtedly very unlike the corn of to-day. Now the discoverer of this grass, if he had entertained the idea of natural law that seems to be prevalent to-day, would have said:

> **This grass has attained its present development through the operation of natural forces, and in accordance with the law of the survival of the fittest. If I should attempt to further its development by any sort of effort, I should be acting contrary to a law of nature and must therefore inevitably fail.**

But he did no such thing. He simply provided conditions under which, through the very operation of this law of the survival of the fittest, a better and better type of corn was produced. Why should we not do the same thing to insure the progress of nations in the direction of peace? The conditions of peace will assure a peaceful type of nation, just as the appropriate environment will produce a better type of corn. What essential difference is there between the mode of producing a "culti-

vated" nation and the mode of producing any other product of cultivation? Clearly there is none at all.

It is surprising, then, that the survival of the fittest, merely because it is a law of nature, should for that reason be supposed to militate against the efforts of man in behalf of peace—national, industrial and social. For if it were not a law of nature that the fittest survive, how could we expect to affect the development of an individual or of a nation by the improvement of circumstances? It would be hopeless to expect any progressive results from our efforts directed to the improvement of conditions if these conditions bore no relation to the type of individual, institution or society that develops within them? It is just because we know that nature acts in accordance with this unfailing law that we may be confident of our ability to determine the fitness either of individual or nation by intelligently controlling the conditions of life. Instead of precluding our efforts at reform or peace the laws of nature, I repeat, reveal the conditions that make possible successful efforts in this direction. If this is true of natural laws in general it is of course true of the law of the survival of the fittest. Everything that nature has developed, everything that survives, proves by its survival that it is among the fittest. In early paleozoic times certain crustacea and mollusks were the highest forms of life; in the mesozoic period huge lizards held sway, and in the miocene age the mastodon was lord of the earth. Why do not all these animals flourish now? It is merely because the "times have changed"; they are no longer the fittest. Have we not here the very secret of achieving progress? Change in conditions produces evolution. If we only change the conditions, then, so that the peaceful type of nation will be the fittest, the warring type will become as extinct as the megatherium or the dodo, and, for exactly the same reason, that is, it will no longer be fit to survive. May we not hope, then, that through the changes that must result from increased social intelligence the peaceful nations by becoming the fittest will take the place of the militant types just as the present flora and fauna of the earth have supplanted the forms of life that immediately preceded them.

In conclusion we may say that the prevalent doctrines that, since the survival of the fittest is a natural law under the operation of which the lower organisms and society have advanced to their present stage of development, we must therefore be careful not to hinder its operation, or seek to abrogate it, is false. Of course, as a matter of fact, nobody should try to "hinder" the operation of a natural law, or "encroach" upon it, and nobody with any knowledge of nature, and solicitous about the realization of ethical ends, would undertake to "abrogate" a natural law except in the sense of counteracting one natural force by another. All that we can do, all that anybody should try to do, is to take advantage of the existence of a natural law so to arrange cir-

cumstances that the result of the operation of that law will be to human advantage, that is to say, that "the fittest" may be "the best." The construction of the pyramids or the Washington Monument did not affect in the least the law of gravitation. The improvement of our grain and our live stock has not in the least affected the law of the survival of the fittest. No more would the development of a society in accordance with the highest qualities of man's nature affect that law. Natural law does not stand in the way of the one achievement any more than the other. The fittest nations will survive; it is for us to make fit the conditions. To assist us in this task is the supreme function and opportunity of science.

*Science, d'où prévoyance; prévoyance, d'où action:* telle est la formule très-simple qui exprime, d'une manière exacte, la relation générale de la *science* et de l'*art*, en prenant ces deux expressions dans leur acceptation totale.[9]

[9] Comte, Auguste, "Philosophie Positive," Vol. I., p. 51.

# A NEGLECTED FACTOR IN THE QUESTION OF NATIONAL SECURITY

By Professor GEORGE F. ARPS
OHIO STATE UNIVERSITY

THE question of national preparation in anticipation of future international strife can not fail to consider man as he natively is, divested of the mantle of acquired behavior; he must be viewed from the standpoint of his naked natural birthright, however much it may be desirable to consider him as we wish him to be, if the question is to be answered on practical rather than idealistic grounds.

By birthright we mean that complex of inherited tendencies as we find it unencumbered, unmodified or redirected by environmental influences. This complex constitutes "original man"; it is man's inborn organization with which he begins his life-long struggle with unescapable environment. Innumerable catalogues have been made of man's native equipment (instincts, reflexes, tendencies) with which he starts the conquest of the external world. It suffices for our purpose to know that man's original complex exceeds in variety of tendencies that of any other animal, and that the virility and dominance of certain tendencies may vary endlessly with the individual.

What a man is, what he will do, is a result of the play of environmental stimuli upon the leanings, bents, tendencies, lodged in his constitution. Native endowment and environment fit each other as lock and key. The limit, character and direction of man's behavior can not transcend his original nature—a "soft pine" germ-plasm spells a soft pine character and this remains true no matter how favorably the environmental forces may be applied. By no pedagogical device has it been, or ever will be, possible to transform a weak inherited complex into an oak character.

The future security of the state or the home must not fail to regard man biologically, as possessed of powerful destructive tendencies as well as powerful tendencies of love, sympathy and kindness. "Two souls," as Faust says, "dwell within his breast," the one of sociability and helpfulness, the other of jealousy and antagonism to his mates. Wanton blindness to this poetic expression of man's dual nature wobbles the security of any nation unwilling to turn the unsmitten cheek. In this matter the evil component of man must be reckoned with the good. To cherish the latter is noble; to blink the former is not only perilous, but beggars courage.

These two apparently contradictory souls lie deeply rooted in the subsoil of man's original constitution. The sense organs like waiting funnels form gateways for environmental stimuli which, seeping through the interstices of acquired behavior, nourish the roots below.

All roots of human action, whether that of parental love or pugnacity, grow according to the degree and mode of exercise until the entire human organism is completely moulded. A nation under the drill of incessant discipline becomes a completely fashioned fighting machine.

Which of these souls, these inborn propensities, have civilized nations through all forms of educational agencies elected to nourish and preserve? Consider the space given to man's brutal activities in the histories of all nations, the melodramatic movies, the devotion of the daily press to executions, thuggery, thievery (all modifications of the Jesse James stimuli); consider, too, the content of pictorial weeklies and certain other periodicals and fictional publications dealing with deep-laid plots of "Man's inhumanity to man." These forces constitute a fair sample of environmental stimuli which arouse, keep alive and feed fat man's original glut to rapine and to plunder, to hate and fear. These are among the forces which determine the self which dominates human behavior. The wave of fear sweeping over the states to-day like a prairie fire is the expected expression of a native protective response to a very real situation. Report from the blood-stained fields of Europe, of the new and dreadful devices for the annihilation of time and space, flashes through the thin veneer of idealism and conventionalities, lays hold on the original springs of human action, brushes aside acquired behavior and strikes quick to the Faustion Self of pugnacity, fear, hatred and antagonism. Like a slow-consuming fire, civilized nations have nursed the demon of destruction which, loosened, rocks the temple of international justice, outrages the peaceful in utter disregard of solemn obligations. And this because fine words and unsupported threats are powerless in the face of deadly impulses armed with refined tools and directed with terrible sincerity to crush and kill. The rôle of these original impulsive forces of man has been recognized by the laymen. In a remarkable address recently delivered in Carnegie Hall, Elihu Root portrays man and civilization in these significant words:

> We have learned that civilization is but a veneer thinly covering the savage nature of man; that conventions, courtesies, respect for law, regard for justice and humanity, are acquired habits, feebly constraining the elemental forces man's nature developed through countless centuries of struggle against wild beasts and savage foes.

The Teutonic war machine is a product of careful nurture from

the cradle of many generations. It is not an accident that military toys are given to children during the most plastic and favorably formative period of life. Inflammable youth is fed upon an inflammable diet morning, noon and night; at no time can his ears, eyes or touch escape those environmental stimuli which fall upon and make permanent his native tendency to combat, to resent, to hate. Out of this stuff European nations wove and are continuing to weave the ideational web of war. The gory field of Europe is the inevitable consequence. So sure as martial ideas are fabricated, so sure as these ideas are persistently entertained, so sure will war result, for it is the very essence of ideas to issue into action.

If it is true that environmental stimuli quicken and actualize latent tendencies and if it is equally true that failure to feed such tendencies during the ripening period tends to weaken, if not eradicate, them, then, the good John Galsworthy's statement that "this war is an operation to excise the trampling instinct" is surely open to serious question. According to the laws of instinctive development, fixation of the trampling instinct rather than excision is the inevitable consequence of the war. The iron heel of the treading, trampling instinct thrives least through inaction and is quickened, sharpened and enthroned by action in a favorable environment. War is such an environment; it unlocks the trampling heel of the dominating, professional Junker as a key loosens the lock. Junkerism resides within the breast of every man in every land and differs from mortal to mortal only in the degree of its original vigor. Excision through opportunity is a myth born of flimsier stuff than paper dreams.

Again let it be said that the question of national security can not fail to consider man's dual and original endowments. Peel off the thin veneer of conventionality, and tap him at his foundation, and one side of him stands revealed as a fighter, full of original pugnacity, anger, resentment and, under provocation, may become the most ruthlessly ferocious of beasts. These "Original Movers" fitted man to survive and are operative to-day under one guise or another. As Rochefoucauld says,

> There is something in the misfortunes of our very friends that does not altogether displease us; and an apostle of peace will feel a certain vicious thrill run through him, and enjoy a vicarious brutality, as he turns to the column in his newspaper at the top of which "Shocking Atrocity" stands printed in large letters. See how the crowds flock round a street brawl! Consider the enormous annual sale of revolvers to persons, not one in a thousand of whom has any serious intention of using them, but of whom each one has his carnivorous self-consciousness agreeably tickled by the notion, as he clutches the handle of his weapon, that he will be rather a dangerous customer to meet![1]

[1] James: "Principles of Psychology."

That man is essentially of pacific virtues rests on an assumption not sustained by his evolutionary or political history.

If it is true that powerful nations systematically nurture the demon of antagonism through all forms of educational agencies, if we rightly interpret the genesis and dynamics of ideas, and if, lastly, the human race is still in the condition of *bellum omnium contra omnes*, then, national preparedness, it seems, becomes a plain matter of duty. There is no alternative, regrettable as it is, so long as nations insist on so organizing from earliest infancy to maturity the brains of their citizens in such a way that any wholly irrelevant stimulus may pull the trigger and let loose the engines of war. Pacific nations, unprepared, but potentially powerful, must submit, under certain circumstances, to indignities which may often amount to nothing short of complete abnegation of self-respect. Who is there who does not *wish* it might be otherwise? But wishes and sentimental longings go down like chaff before the wintery blasts of energetic action. The present world disturbance demands intelligence, cold calculation, action; this is no time for any nation to swim about in a weltering sea of sensibility and emotion, no time for spineless fulminations and dreams. Nor will it be maintained that similar situations will not recur. In view of recent events, in view of what man is and what he has shown himself to be on every page of his bloody history, it would be folly, and in the long run suicidal, for any vigorous people to close deliberately their eyes to the simplest laws of human behavior.

Imperative as preparation now appears, it will be even more so after the war by reason of untold increment of economic stresses which strain immeasurably man's native good will. Future economic struggles and practises may inaugurate a low grade of trade ethics far removed from the altruistic soothing-syrup variety. The blamelessly enriched onlooker, with almost fatal surety, acts as a salve which heals the wounds, buries the differences of fierce antagonists and, under economic stresses, this onlooker incurs the unrighteous, united envy and secret, if not open, hatred of the combatants. The best is not even to be hoped for; the worst may be expected.

# THE ORIGIN AND EVOLUTION OF LIFE ON THE EARTH*

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## LECTURE II, PART I

## *The Evolution of the Vertebrata*

**Chromatin evolution. Errors and truths in the Lamarckian and Darwinian explanations. Individuality in character origin, velocity and cooperation. Origin of the vertebrate type. The laws of convergence, divergence and of adaptive radiation in fishes and amphibians.**

SIMON NEWCOMB[1] considered the concept of the rapid movement of the solar system toward Lyra as the greatest which has ever entered the human mind. The history of the vertebrates as the visible expression of the evolution of the microscopic chromatin presents a contrasting concept of the potentialities of matter in the infinitely minute state.

The peculiar significance of vertebrate chromatin is its stability in combination with incessant plasticity and adaptability to varying environmental conditions and new forms of bodily action; throughout constant changes of proportion, gain and loss of characters, genesis of new characters, there is always preserved a large part of the history of antecedent form and function, for chromatin is far more stable than the surface of the earth. In the vertebrates chromatin evolution is mirrored in the many continuous series of forms which have been discovered, also in the perfection of mechanical detail in organisms of titanic size and inconceivable complexity, like the dinosaurs among reptiles and the whales among mammals which rank with the *Sequoia* among plants.

There are two historic explanations of the causes of this wonderful process of chromatin evolution, each adumbrated in the Greek period of inquiry. The older, known as the Lamarckian, expressed in modern terms is that *the beginning of new form and new function is to be sought in the body cells* (*soma*), on the supposition that cellular actions,

* Fourth course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the Academy at Washington, on April 17 and 19, 1916.

The author desires to express his special acknowledgments to Professor William K. Gregory of Columbia University and the American Museum of Natural History for notes and suggestions in the preparation of this section.

[1] Newcomb, Simon, "Astronomy for Everybody," Doubleday, Page & Co. November, 1902, 12mo, pp. 333.

reactions and interactions with each other and with the environment are heritable by the chromatin. This idea was originally suggested by the accurate observation of early naturalists and anatomists that bodily function not only controls form but is generally adaptive or purposive in its effects. According to this Lamarck-Spencer-Cope explanation a change of environment, of habit and of function should always be antecedent to changes of form in succeeding generations; moreover, if this explanation were the true one, successive changes in evolutionary series would be like growth, they would be observed to follow the direct lines of individual action, reaction and interaction, the young would be increasingly similar to the adults of antecedent generations, which is frequently the case but unfortunately for the Lamarckian explanation is not *invariably* the case.

The opposed explanation, the Darwinian, as restated by Weismann and De Vries, is that *the beginning of new form and function is to be sought in the germ cells or chromatin.* This is based upon the direct anti-Lamarckian view that the actions, reactions and interactions which cause certain bodily organs to originate, to develop, or to degenerate, to exhibit momentum or inertia in development, are not inherited and do not give rise to corresponding sets of predispositions in the chromatin. According to this explanation all predispositions to new form and function not only begin in the germ cells but are more or less lawless or experimental, they are constantly being tested or tried out by bodily experience, habits and functions. Technically stated they are fortuitous variations followed by selection of the fittest variations. Thus Darwin's disciple, Poulton, also De Vries, who has merely restated in his law of "mutation" Darwin's original principle of 1859, and Bateson, the most radical thinker of the three, hold the opinion that there is no adaptive law observed in variation but that the chromatin is continuously experimenting and that from these experiments selection guides the organism into adaptive and purposive lines.

ENVIRONMENTAL CORRELATION. ADAPTATIONS OF RESPIRATORY, OLFACTORY, VISUAL, AUDITORY, THERMAL, GRAVITY FUNCTIONS AND ORGANS TO VARIATIONS OF LIGHT, HEAT, HUMIDITY, ARIDITY, CAUSED BY MIGRATIONS OF THE INDIVIDUAL OR OF THE ENVIRONMENT, COORDINATIVE AND CORRELATIVE

INTERNAL CORRELATION
CORRELATION AND COORDINATION OF THE INTERNAL GROWTH AND FUNCTIONS THROUGH INTERNAL SECRETIONS (ENZYMES) AND THE NERVOUS SYSTEM

ADAPTATIONS TO NUTRITION
(1) ON INORGANIC COMPOUNDS
(2) ON BACTERIA
(3) ON PROTOPHYTA, ALGAE, ETC.
(4) ON PROTOZOA
(5) ON HIGHER PLANTS, HERBIVOROUS DIET
(6) ON HIGHER ANIMALS, CARNIVOROUS DIET
(7) PARASITIC, WITHOUT OR WITHIN PLANTS AND ANIMALS

ADAPTATIONS TO INDIVIDUAL COMPETITION AND SELECTION
(A) SELECTION, AFFECTING VARIATION, RECTIGRADATION, MUTATION, ORIGIN AND DEVELOPMENT OF SINGLE CHARACTERS, PROPORTIONS, ETC.
(B) AFFECTING ALL REPRODUCTIVE ORGANS, PRIMARY AND SECONDARY

ADAPTATIONS OF RACIAL COMPETITION AND SELECTION
AFFECTING CHIEFLY ALL MOTOR, PROTECTIVE, OFFENSIVE, AND DEFENSIVE STRUCTURES OF THE ENDO- AND EXOSKELETON; ALSO REPRODUCTION RATE

*a.* The peculiar significance of vertebrate chromatin is its stability in combination with incessant plasticity and adaptability to varying environmental conditions and new forms of bodily action.

Neither the Lamarckian nor the Darwinian explanation accords

with all that we are learning through paleontology and experimental evolution of the actual modes of the origin and development of adaptive characters. That there are elements of truth in each explanation is evident from the following. Adaptive characters present three phases: first, the *origin* of character-form and character-function; second, the more or less rapid *acceleration* or *retardaton* of character-form and function; third, the *coordination* and *cooperation* of character-forms and functions. If we adopt the physico-chemical theory of the origin and development of life it follows that the causes of such origin, velocity (acceleration or retardation) and cooperation must lie somewhere within the actions, reactions and interactions of the four physico-chemical complexes, namely, the physical environment, the developing organism, the chromatin, the living environment, because these are the only reservoirs of matter and energy we know of in life history. While it is possible that the relations of these causes will never be fathomed, it is certain that our search must proceed along the line of determining which actions, reactions and interactions invariably precede and which invariably follow, those of the body-cells (Lamarckian view) or those of the chromatin (Darwinian-Weismann view).

The Lamarckian view that adaptation in the body cells *invariably* precedes similar adaptive reaction in the chromatin is supported neither by experiment nor by observation; such precedence while occasional and even frequent is by no means invariable. The Darwinian view, namely, that chromatin evolution is a matter of fortuity and displays itself in a variety of directions, is contradicted by paleontological evidence both in the Invertebrata and Vertebrata, among which we observe that continuity in chromatin evolution prevails over the evidence either of fortuity or of sudden leaps or mutations, that *in many characters there is a prolonged rectigradation or direct evolution of the chromatin toward adaptive ends.* This is what we mean in saying that in evolution law prevails over chance.

Darwin's quest for the origin of *species* having become an incidental issue, the chief quest of evolutionists to-day is the origin and history of *single characters.* The discoveries of modern paleontology are in accord with many of the recently discovered laws of heredity, which will be described in the succeeding course of the Hale Lectures. Paleontology supports heredity in demonstrating that every vertebrate organism is a mosaic of an inconceivably large number of "characters" or "character-complexes," structural and functional, some indissolubly and invariably grouped and cooperating, others singularly independent. For example, every one of the most minute scales of a reptile or hairs of a mammal is a "character complex" having particular chemical formulæ and chemical energies which condition the shape, the color, and the function and all other features of the complex. Through re-

searches on heredity each of these character complexes is now believed to have a corresponding physico-chemical determiner or group of determiners in the germ chromatin, the chromatin existing not as a miniature but as an individual *potential and causal.*

The *principle of individuality,* namely, of separate development and existence, which we have seen to be the prime characteristic of the first chemical assemblage into an organism (p. 179), also governs each of these character complexes. In some vertebrates we observe an infinity of similar character complexes evolving in an exactly similar

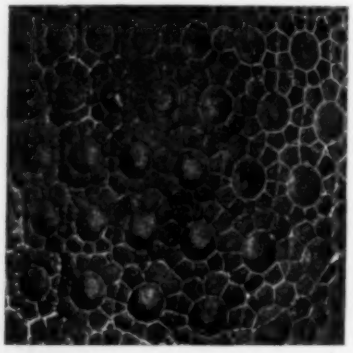


FIG. 1. SHELL.

FIG. 2. TOOTH.

manner, as in the beautiful markings of the shell and the exquisite enamel pattern of the teeth of the glyptodon, in which every portion of the shell evolves similarly, and every one of the teeth evolve similarly, from which we might conclude that there is an absence of individuality in form-characters and that some homomorphic (similarly formative) impulse is present in all characters of similar ancestry; but this rash conclusion is offset by the existence of other character complexes of similar ancestry which each evolve differently, or are in a high degree heteromorphic (diversely formative), as, for example, in the grinding teeth of mammals.

This individuality and separability inherent in character-form is equally observed in character-velocity, and is at the basis of the shifting of characters and of all the proportionate and quantitative changes which make up four-fifths of vertebrate evolution. For example, two character-forms side by side may evolve with equal velocity and maintain a perfect symmetry or one may be accelerated into very rapid

momentum,[2] while the other may be retarded into a state of absolute inertia or equilibrium. These are the extremes of character-velocity which result in the states known as *development, balance* and *degeneration*. In many parts of the skeleton development and degeneration so obviously follow use and disuse that Cope was led to propose a law of Bathmism (growth force) and to explain the energy phenomena of use and disuse in the body tissues as the *cause* of the appearance of corresponding energy potentialities in the chromatin. In other words, that the energy of development or of degeneration in the bodily parts of the individual is inherited by corresponding parts in the germ. As pointed out above, the defect in this supposed law consists in its not being invariably applicable.

FIG. 3. FIRST UPPER MOLAR OF *Meniscotherium terrærubræ*.
FIG. 4. FIRST UPPER MOLAR OF *Euprotogonia puercensis*.

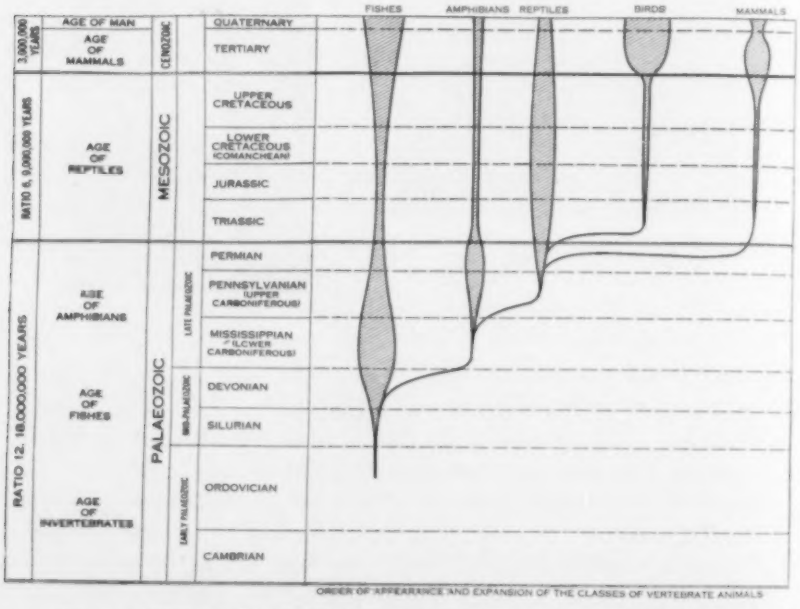



FIG. 5. ORDER OF GEOLOGIC APPEARANCE AND EPOCHS OF MAXIMUM ADAPTIVE RADIATION (EXPANSION) AND DIMINUTION (CONTRACTION) OF THE FIVE CLASSES OF VERTEBRATED ANIMALS. Prepared by Osborn and Gregory.

[2] In physics momentum equals mass × velocity. In biology momentum and inertia refer to the relative rate of character change both in individual development (ontogeny) and in evolution (phylogeny). *Character-parallax* would express the differing velocities of two characters. Thus the character-parallax of the right and left horns in the Brontotheriinæ (titanotheres) is very small, *i. e.*, they evolve at nearly or quite the same rate; on the other hand, the character-parallax between the premolar teeth in these animals is very great. The char-

Changing bodily form and function and the ever changing velocity in character-complexes is to be regarded as an expression of physico-chemical energy resulting from the actions, reactions and interactions of different parts of the organism, and, as repeatedly stated in these lectures, the only vista which we enjoy at present into the causes of character-origin, character-velocity and character-cooperation is through chemical catalysis, namely, through the hypothesis that actions and reactions of form and of motion liberate specific catalytic messengers in the nature of ferments, enzymes, hormones, which produce specific and cooperating interactions in every character-complex of the organism. In our survey of the marvelous evolution of the vertebrates we may constantly keep in mind the concept of the actions, reactions and interactions of the hard parts of the structural tissues, which are preserved in fossils. In this field of observation the chemical and physiological influences of the body can only be inferred and the relations of these physico-chemical influences to those of the chromatin are absolutely unknown. Yet changes in the bodily hard parts invariably mirror the evolution of the chromatin, in fact, this evolution is nowhere revealed in a more extraordinary manner than in the incessantly changing characters in such hard parts as the labyrinthine foldings of the deep layers of enamel in the grinding teeth of the horse. This evolution of the hard parts in adaptation resolves itself into six chief and concurrent phenomena, namely:

FIG. 6. GEOLOGIC TIME SCALE. Prepared by the author and C. A. Reeds after Schuchert.

acter-parallax idea has innumerable applications and can be expressed quantitatively.—W. K. GREGORY.

| | |
|---|---|
| Ever changing character-form and character-function, | Characters and Character-Complexes |
| Ever changing character-velocity in individual development and in the chromatin, | |
| Ever changing character-cooperation, coordination and correlation, | |
| Incessant character-origin in the chromatin, sometimes following, sometimes antecedent to character-origin in the organism, | |
| Relatively rapid disappearance of character-form and -function in the individual, | |
| Relatively slow disappearance of character-form and -function in the chromatin. | |

## FORM EVOLUTION OF THE VERTEBRATES UNDER THE MECHANICAL AND PHYSICO-CHEMICAL ACTIONS, REACTIONS AND INTERACTIONS OF LOCOMOTION, OFFENSE AND DEFENSE, AND REPRODUCTION[3]

Ordovician time, the early Paleozoic epoch next above the Cambrian, is the period of the first known vertebrates, the fossil remains of fish dermal defenses found near Cañon City, Colorado, as announced by Walcott in 1891, and subsequently in the region of the present Big Horn Mountains of Wyoming and the Black Hills of South Dakota. Small spines referred to Acanthodian sharks are also abundant in the Ordovician of Cañon City, Colorado. Since they were slow-moving types protected with the beginnings of a dorsal armature composed of small calcareous tubercles, to which the group name Ostracoderm refers, probably these earliest known pro-fishes were not primitive in external form but followed upon a long antecedent stage of vertebrate evolution. In the form-evolution of the vertebrates relatively swift-

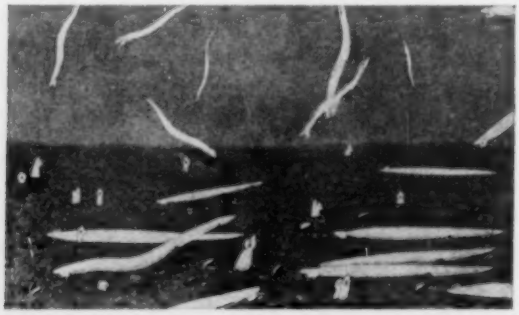


FIG. 7. THE EXISTING LANCELETS (*Amphioxus*), fusiform protochordates, living in the littoral zone the sole survivors of an extremely ancient stage of vertebrate evolution. After Willey.

moving, defenseless types are invariably antecedent to slow-moving, armored types.

Ancestral to these Ordovician vertebrates were free-swimming,

[3] For the geologic history the author is chiefly indebted to his fellow academician, Charles Schuchert. For the latest knowledge regarding the evolution of the vertebrates to his Columbia University colleague, William K. Gregory.

quickly darting types of unarmored fishes. The double pointed, fusiform body, in which the segmented propelling muscles are external and a stiffening notochord is central, is the fish prototype, which more or less clearly survives in the existing lancelets (*Amphioxus*) and in the larval stages of the degenerate Ascidians. These animals furnish numerous embryonic and larval proofs of descent from nobler types.

Taking the whole history of vertebrate life from the beginning, we observe that every prolonged adaptive phase in a similar habitat becomes impressed in the hereditary characters of the chromatin, which throughout the development of new adaptive phases always retains more or less potentiality of repeating the embryonic, immature, and even the mature structures of older adaptive phases of older environments. The chromatin is at once the most conservative and the most progressive center of physico-chemical evolution; it records past adaptations, it meets the emergencies of the present through the adaptability which it imparts to the organism in its distribution throughout every living cell; it is continuously giving rise to new characters and functions. This law of ancestral repetition, formulated by Louis Agassiz

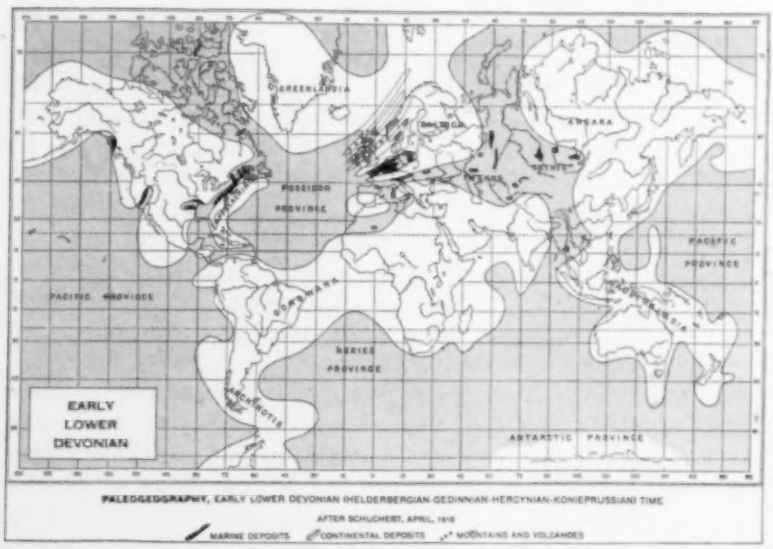



FIG. 8. PERIOD OF THE EARLY APPEARANCE OF TERRESTRIAL INVERTEBRATES AND VERTEBRATES. Paleogeography of the earth in early Lower Devonian time, showing the hypothetical southern continent *Gondwana* and the Eurasiatic inland sea *Tethys*, according to the hypotheses of Suess. After Schuchert, 1916.

and developed by Haeckel and Hyatt, dominated biological thought during thirty years of the nineteenth century (1865–1895), and with more or less success a highly speculative solution of the ancestral history of the vertebrates was sought in embryonic development and com-

parative anatomy long before the actual lines of evolutionary descent were determined through paleontology.

The form-evolution of the backboned animals, beginning with these pro-fishes of Cambrian and Pre-Cambrian time, extends over a period of 30,000,000 years. The supremely adaptable vertebrate body type begins to dominate the living world, overcoming one mechanical difficulty after another as it passes through the habitat zones of water, land and air. Motions necessary for the capture, storage and release of plant and animal energy continue to control the form of the body and of its appendages, but in the meantime the organism through mechanical and chemical means protects itself either offensively or defensively and also adapts itself to reproduce and protect its kind, according to Darwin's original conception of the struggle for existence as involving both the life of the individual and the life of its progeny. Among all defenseless forms speed is a prime necessity, while all heavily armored forms gradually abandon mobility. As among the Invertebrata, calcium carbonate and phosphate and various compounds of keratin and chitin are the chemical materials of armature. Locomotion, as distinguished from that in all invertebrates, is in an elongate body stiffened by a central axis. The evolution of the skeletal supports (endoskeletal) and limbs is generally from the center of the body (notochord) toward the periphery, the evolution of the defensive armature (exoskeleton) is from the periphery toward the center. The defensive armature finally, through change of function, makes important contributions to the inner skeleton.

## THE LAW OF CONVERGENCE OR PARALLELISM IN LOCOMOTOR, OFFENSIVE AND DEFENSIVE ADAPTATIONS

Although the structural body type and mechanism of locomotion is profoundly diverse, there arise hundreds of adaptive parallels between the Vertebrata and the antecedent evolution of the Invertebrata. The combined necessity for protection and locomotion brings about close parallels in body form between such primitive Silurian eurypterids as *Bunodes* and the vertebrate Ostracoderms, a superficial resemblance which has led Patten[4] to defend the view that the two groups are genetically related.

The theoretic application of the fundamental law of action, reaction and interaction becomes increasingly difficult as adaptations multiply and are superposed upon each other with the evolution of the four physico-chemical relations, as follows:

[4] Patten, Wm., "The Evolution of the Vertebrates and their Kin," 8vo, P. Blakiston's Son & Co., 1912, 486 pp., 309 figs.

| | |
|---|---|
| Physical environment, succession, reversal and alternation of habitat zones, | Incessant Selection and Competition |
| Individual development, succession, reversal and alternation of adaptive phases, | |
| Chromatin evolution, addition of the determiners of new adaptations while preserving the determiners of old adaptations, | |
| Succession of life environments. | |

Yet it must be the similarity of these internal physico-chemical energies of protoplasm and the similarity in the mechanics of motion, of offense and defense, which underlies the law of convergence or parallelism in adaptation, namely, *the production of externally similar forms in adaptation to externally similar natural forces,* a law which escaped the keen observation of Huxley[8] in his remarkable analysis of the modes of vertebrate evolution published in 1880.

The whole process of motor adaptation in the vertebrates, whether the fishes, amphibians, reptiles, birds, or mammals, is the solution of a series of mechanical problems, adjustment to gravity, overcoming the resistance of water or air in the development of speed; in the evolution of the limbs of creating levers, fulcra (joints) and pulleys. The fore and hind fins of fishes and the fore and hind feet of mammals evolve uniformly where they are homodynamic and divergently where they are heterodynamic. This principle of homodynamy and heterodynamy applies to the body as a whole and to every one of its parts, according to two laws: first, that each individual part has its own mechanical evolution, and, second, that the same mechanical problem is generally solved on the same principle. This we observe is invariably the ideal principle, for unlike man nature wastes little time on inferior inventions but immediately proceeds to superior inventions.

The three mechanical problems of existence in the water habitat are: first, overcoming the buoyancy of water either by weighting down, increasing the gravity of the body, or by the development of special gravitating organs which enable animals to rise and descend in this medium; second, the mechanical problem of overcoming the resistance of water in rapid motion which is accomplished by means of warped surfaces and well-designed entrant and reentrant angles of the body similar to those of the fastest modern yachts; third, the problem of propulsion of the body, which is accomplished, first, by sinuous motion of the entire body terminating in the powerful propulsion of the tail fin, secondly, by supplementary action of the four lateral fins, third, by the horizontal steering of the body by means of the median system of fins.

[8] Huxley, T. H., "On the Application of the Laws of Evolution to the Arrangement of the Vertebrata, and more Particularly of the Mammalia," *Proc. Scientific Meetings of the Zoological Soc. of London for the year 1880,* pp. 649–662. (Read December 14, 1880.)

The terrestrial and aerial evolution of the four-limbed types (Tetrapoda) is designed chiefly to overcome the resistance of gravity and in a less degree the resistance of the atmosphere through which the body moves. When the aerial stage evolves, with increasing speed the resistance of the air becomes only slightly less than that of the water in the fish stage, and the warped surfaces, the entrant and reentrant angles evolved by the flying body are similar to those of the rapidly moving fishes.

### BRANCHING OR DIVERGENCE OF FORM, THE LAW OF ADAPTIVE RADIATION

In general the *law of divergence* of form, perceived by Lamarck and rediscovered by Darwin, has been expanded by Osborn into the modern *law of adaptive radiation,* which expresses the differentiation of animal form radiating in every direction in response to the necessities of the quest for nourishment and the development of new forms of motion in the different habitat zones. *Divergence* is constantly giving rise to differences in structure, while *convergence* is constantly giving rise to resemblances of structure. In contrast with this divergent principle is the *convergence* brought about by the similarity above described of the physico-chemical laws of action, reaction and interaction and the similarity of the mechanical obstacles encountered by the different races of animals in similar habitats and environmental media.

The chief advance which has been made in the last fifty years is our abundant knowledge of the *modes* of adaptation as contrasted with the very limited knowledge yet attained as to the *causes* of adaptation. The law of adaptive radiation is a law expressing the modes of adaptation of form, which falls under the following great principles:

**Law of Adaptive Radiation of Form**

1. **Divergent adaptation, by which the members of the primitive stock tended to develop differences of form while radiating into a number of habitat zones.**
2. **Convergent adaptation, whereby animals from different habitat zones enter a similar habitat zone and acquire many superficial similarities of form.**
3. **Direct adaptation, for example, in primary migration through an ascending series of habitat zones, aquatic or terrestrial, arboreal, aerial.**
4. **Reversed adaptation, where secondary migration takes the reverse direction from aerial to arboreal, to terrestrial, to aquatic habitat zones.**
5. **Alternate adaptation, where the animal departs from an original habitat and primary phase of adaptation, and then returns from the secondary phase of adaptation to a more or less perfect repetition of the primary phase by returning to a primary habitat zone.**
6. **Symbiotic adaptation, where vertebrate forms exhibit reciprocal, or interlocking adaptations with the evolution of other vertebrates or invertebrates.**

Prolonged residence in a single habitat zone results in profound alterations in the chromatin, and in consequence the history of past phases is more or less clearly recorded. It is very important to keep in mind that the body and limb form developed in each adaptive phase is the starting point of the next succeeding phase.

Among the disadvantages of prolonged zonal existence are the following. Through the law of compensation, discovered by Geoffroy St. Hilaire early in the last century, every vertebrate in developing and specializing certain organs sacrifices others; for example, the lateral digits of the foot of the horse are sacrificed for the evolution of the central digit as the animal evolves from tridactylism to monodactylism. These sacrificed parts are never regained; the horse can never revert to the tridactyl condition although it might reenter the habitat zone in which three digits on each foot would serve the purposes of locomotion better than one. In this sense chromatin evolution is irreversible. The extinction of vertebrate races has generally been due to the fact that the various types have sacrificed too many characters in their physiological reactions to a particular life habitat zone. A finely specialized form representing a perfect mechanism in itself which closely interlocks with its physical and living environment reaches a *cul de sac* of structure from which there is no possible emergence by adaptation to a different physical environment, or habitat zone. It is these two principles of the non-revival of characters once lost by the chromatin and of too close adjustment to a single environment which underly the law that the highly specialized and most perfectly adapted types become extinct, while primitive, conservative and relatively unspecialized types invariably become the centers of new adaptive radiations.

HABITAT MIGRATIONS OF THE INDIVIDUAL

MIGRATIONS OF THE ENVIRONMENT

AERIAL
(FLYING, VOLANT, TYPES)

AERO-ARBOREAL
(PARACHUTE, GLISSANT, TYPES)

ARBOREAL
(CLIMBING, LEAPING, BRACHIATING TYPES)

ARBOREO-TERRESTRIAL
(WALKING AND CLIMBING, SCANSORIAL, TYPES)

TERRESTRIAL
(AMBULATORY, SLOW; CURSORIAL, RAPID; SALTATORY, LEAPING; GRAVIPORTAL, SLOW, CUMBROUS, MUTIPEDAL, QUADRUPEDAL, BIDEDAL, APODAL, ETC.)

TERRESTRIO-FOSSORIAL
(WALKING AND BURROWING TYPES)

FOSSORIAL
(BURROWING TYPES)

TERRESTRIO-AQUATIC
(AMPHIBIOUS TYPES)

AQUATIC
(SURFACE-LIVING, BOTTOM-LIVING, SWIFT-CURRENT, SLOW-CURRENT)

FLUVIATILE
(FRESHWATER, FLUVIO-MARINE TYPES)

LITTORAL
(SURFACE AND FOSSORIAL TYPES)

PELAGIC
(FREE SURFACE-LIVING, DRIFTING, FLOATING, SELF-PROPELLING TYPES)

ABYSSAL
(DEEP BOTTOM-LIVING TYPES, SLOW AND SWIFT-MOVING)

*b.* The Thirteen Chief Vertebrate Habitat Zones, each of which is divided into many subzones.



*(To be continued)*

# THE PROGRESS OF SCIENCE

## *THE ORGANIZATION OF INDUSTRY AND OF SCIENTIFIC RESEARCH*

In the United States, as well as in England, steps are being taken toward a more effective organization of industrial and scientific work. A Council of National Defense was established by the congress at the close of its session and the president has now announced the appointment of an advisory commission to consist of Daniel Willard, president of the Baltimore and Ohio Railroad; Samuel Gompers, president of the American Federation of Labor; Dr. Franklin H. Martin, of Chicago; Howard E. Coffin, of Detroit; Bernard Baruch, of New York; Hollis Godfrey, of Philadelphia, and Julius Rosenwald, of Chicago.

With these appointments the president gave out a statement in which he said:

> The Council of National Defense has been created because the congress has realized that the country is best prepared for war when thoroughly prepared for peace. From an economic point of view there is now very little difference between the machinery required for commercial efficiency and that required for military purposes. In both cases the whole industrial mechanism must be organized in the most effective way. Upon this conception of the national welfare the council is organized, in the words of the act, for "the creation of relations which will render possible in time of need the immediate concentration and utilization of the resources of the nation." The organization of the council likewise opens up a new and direct channel of communication and cooperation between business and scientific men, and all departments of the government, and it is hoped that it will, in addition, become a rallying point for civic bodies working for the national defense.

At the same time the National Research Council, to the plans for which attention was called in the September issue of the MONTHLY, has been organized under the auspices of the National Academy of Sciences. Some forty members have been appointed with Dr. George E. Hale, director of the Mt. Wilson Solar Observatory, as chairman, Dr. Cary T. Hutchinson, secretary of the Engineering Foundation, as secretary, and Dr. J. J. Carty, chief engineer of the American Telephone and Telegraph Company, as chairman of the executive committee. Special committees have been appointed to report on research in educational institutions, on the promotion of industrial research, on a national census of research, and on other subjects. The National Council is fortunate in having brought together engineers and those engaged in laboratory research, men in the industries, in the universities, in the research foundations and in the government service.

With the Naval Consulting Board we thus have three advisory councils or committees appointed under government auspices with a view to "preparedness." As the president states "the country is best prepared for war when thoroughly prepared for peace," and it would probably be wise for the Research Council of the National Academy to abandon the direct reference to war under which it was created and to confine its efforts to improving the conditions under which scientific research can be undertaken in this country, more especially in the direction of establishing fruitful relations between workers in the so-called "pure" sciences and in the industries.

In Great Britain the first annual report of the Committee of the Privy Council for Scientific and Industrial Research has been issued. The main body of the report is supplied by the advisory council of the committee, of which Sir William McCormick is chairman. After a brief account of the existing institutions for the scientific study of trade

problems, the council goes on to say that other machinery and additional state assistance are absolutely necessary for the purpose. But it needed the shock of the war to make this manifest. The council decided first of all to save as many as possible of the researches which were being conducted before the war and were in danger of abandonment, and recommended the payment of a series of grants. They also have under consideration the possibility of inducing firms in at least some of the industries to assist the progress of research by informing them in confidence of the problems they have in hand or in contemplation. The universities, it is contended, can and must be the main sources of research in pure science, the discoveries in which lie at the root of all practical and technical applications. But they will not be able to do their fair share unless they can attract more students and larger funds.

President Wilson in appointing the advisory board remarks: "In the present instance, the time of some of the members of the advisory board could not be purchased. They serve the government without remuneration, efficiency being their sole object and Americanism their only motive." It may, however, be questioned whether service without remuneration promotes efficiency. The English committee of the Privy Council is doubly amateurish, not consisting of scientific men and not being paid. This may be in accord with aristocratic traditions, but in a democracy men should be paid the value of their services. Advice given without charge and without responsibility is usually worth no more than it costs.

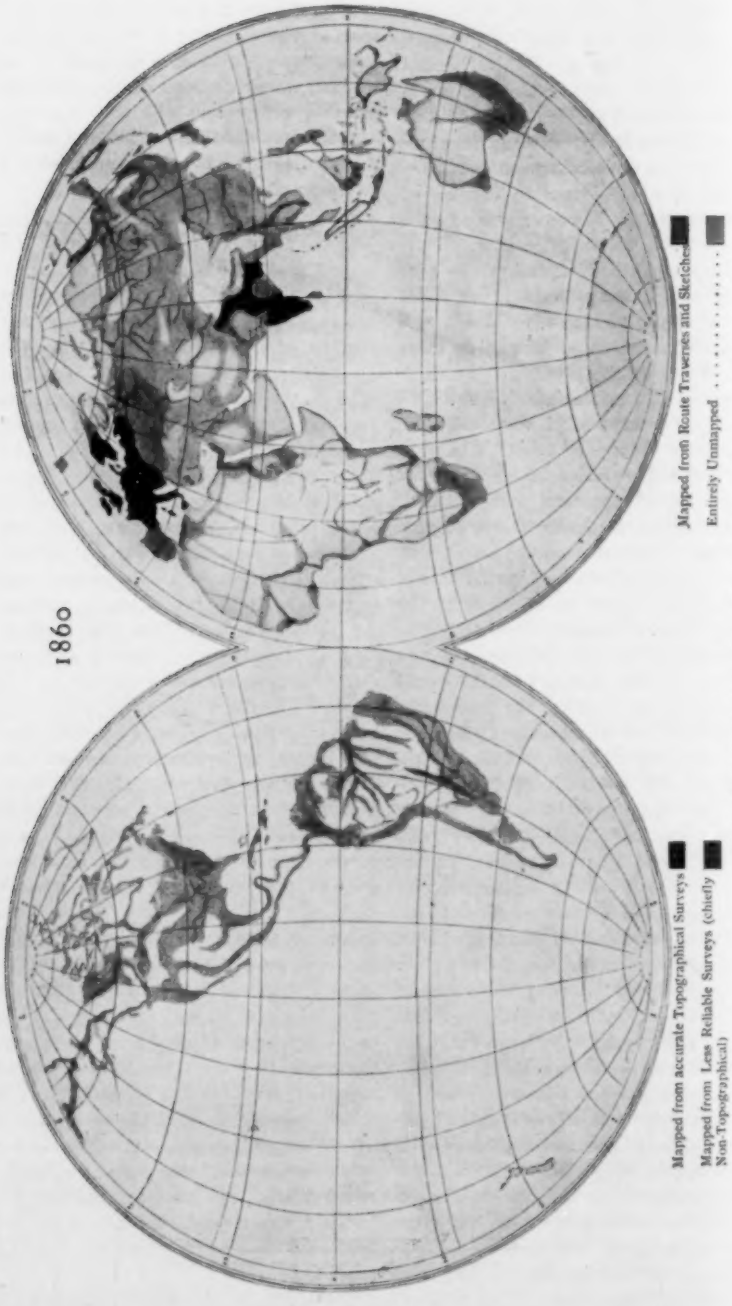
But these various advisory scientific and industrial commissions are important as indicating an awakening of public interest to the place of science under the government. It may be that in due time the scientific and expert functions of the government will be recognized as coordinate with its legislature, executive and judicial departments. A supreme court to interpret the "laws of nature" is not required, but we do need a paid board of scientific men, as far removed from prejudice and politics as the justices of the supreme court should be, and as expert in science as they are in the law, whose decision on questions of scientific policy and scientific appointments should be final within the limits of the laws and the appropriations passed by the congress.

## *PROGRESS IN THE MAPPING OF THE EARTH*

In his presidential address before the Geographical Section at the recent meeting of the British Association for the Advancement of Science Mr. Edward A. Reeves described the progress that has been made in surveying and mapping the earth since 1880, and there are here reproduced two maps which were presented at the meeting.

The maps are drawn on an equal area projection, that is to say, a certain area on the map, such as a square inch, everywhere represents the same area on the earth's surface. The idea kept in view in drawing the maps is that the shade deepens as the accuracy of the surveys increases. (1) The parts that are topographically mapped from triangulation or rigorous traverses are shown by the darkest tint; (2) those that are less accurately mapped from surveys chiefly non-topographical, and of which in many places the basis consists to a great extent of disconnected land-office and property plans, are shown by the tint next in density; and then the next lightest tint (3) represents the parts of the world that are only mapped from route-surveys or rough traverses of explorers. Although these traverses vary greatly in degree of accuracy, they can not be considered so reliable as the surveys shown by either of the other two shades, and in many cases the mapping consists of the roughest sketches. (4) The regions that are entirely unsurveyed and unmapped are indicated by the lightest tint of all, almost white.

Referring to the state of surveys in the Eastern Hemisphere in 1860, it will be seen that outside the continent of

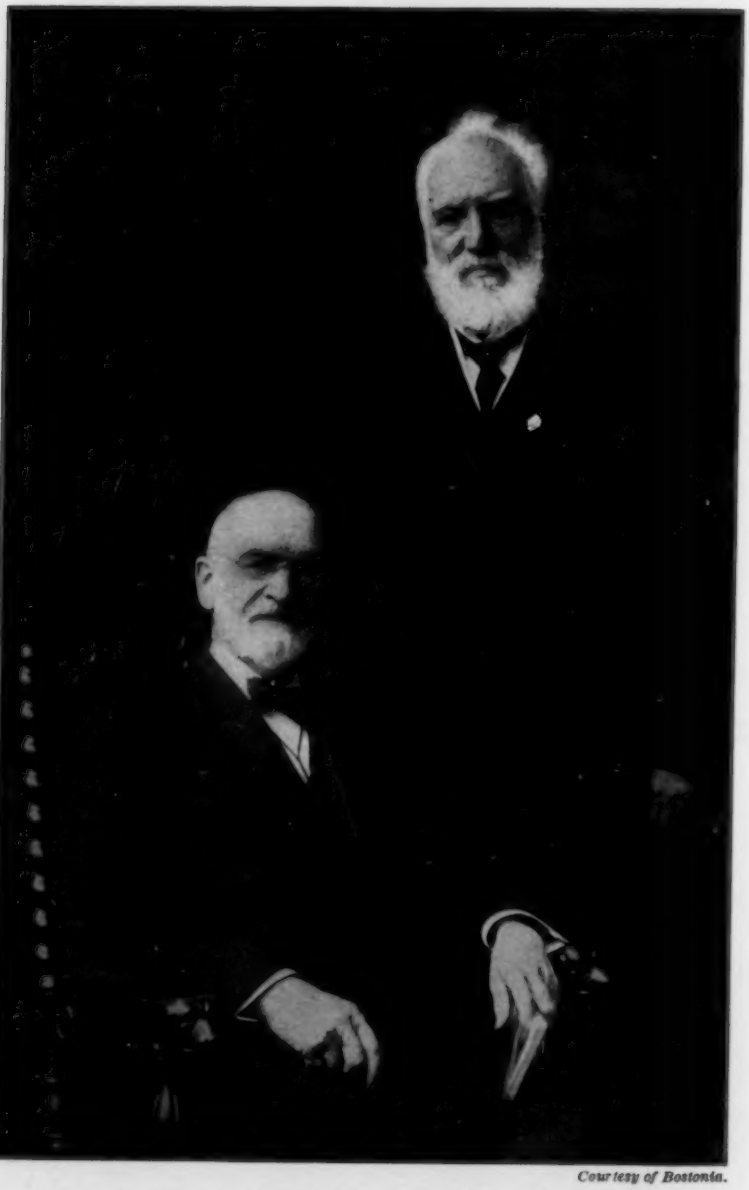

1860
Mapped from accurate Topographical Surveys
Mapped from Less Reliable Surveys (chiefly Non-Topographical)
Mapped from Route Traverses and Sketches
Entirely Unmapped

MAP OF THE EARTH. Surveys in 1860.

1916

Mapped from accurate Topographical Surveys
Mapped from Less Reliable Surveys (chiefly Non-Topographical)
Mapped from Route Traverses and Sketches
Entirely Unmapped

MAP OF THE EARTH. Surveys in 1916.



*Courtesy of Bostonia.*

ALEXANDER GRAHAM BELL AND WILLIAM FAIRFIELD WARREN.

Dr. Bell (who is shown standing) was professor of the mechanism of speech in the School of Oratory of Boston University from 1874 to 1879, while Dr. Warren was president of the university. Dr. Warren in his annual reports makes frequent reference to Dr. Bell's discovery and perfection of the telephone in 1875 and 1876. In 1878 Dr. Bell was invited to lecture at Oxford, and in his next annual report Dr. Warren says that "this is the actual initiation of a practice of international academic exchange which is destined to grow into proportions of the highest import."

Europe, where a considerable extent of accurate surveying had been carried out, the only country where any mapping, based upon triangulation, had been done was India. These areas are shown in the darkest shading. In Europe, France, British Isles, Germany, Austria, Italy, Russia, Switzerland, Denmark, the Netherlands, and Scandinavia had already made a good commencement with their government maps based upon trigonometrical surveys, but these were in several cases by no means complete. India has been noted for the excellency of its surveys ever since the days of Major Lambton, who started the work in 1804, and Colonel Everest, who succeeded him as head of the surveys after Lambton's death in 1823.

In the parts of the Eastern Hemisphere that were surveyed and mapped in the second degree of accuracy, that is, those shown by the next tint, may be included most of the remaining parts of Europe, Egypt, and parts of Algeria near the coast. For the rest such mapping as was done was based upon rough route-sketches, shown by the third tint. In this must be included practically all that was known of the African continent, such as the explorations of Mungo Park, Beke, Livingstone, Speke and Grant, and others, as well as the early exploratory surveys in Central Asia and Australia. The regions that were entirely unsurveyed and unmapped at this time were enormous in their extent, and included not only the Polar regions, but vast areas of Central Africa, Asia and Australia.

Turning to the Western Hemisphere, we find that at this date no triangulation of any extent had been carried out. The U. S. Coast and Geodetic Survey had made a good start, but their work had been confined to the coastline or districts near the coast. There had been La Condamine's attempt at measuring an arc of the meridian near Quito in South America in 1736, the measurement of the Mason and Dixon line, and their survey of the boundary between Pennsylvania and Maryland, in the latter part of the same century; but neither of these resulted in any serious topographical mapping. Such surveys as existed of the interior parts of the United States in 1860, although they varied as regards their merits and degree of dependence, could not be considered as anything but approximate. Some parts of the eastern states are shaded with a tint of the second density, but, with this exception, such mapping as had been done either in North or South America can not be considered of a higher order than route-traversing and sketching, and is tinted accordingly.

Referring now to the 1916 map on which the same shades of tints have the same meaning as on the previous map, the parts that are accurately surveyed from a topographical point of view, based upon triangulation or rigorous traverses, have greatly increased in extent, and these now represent about one seventh of the total area of the land-surface of the earth, instead of only one thirtieth, as was the case in 1860. Remarkable progress has also been made with regard to both of the less accurate kinds of surveying and mapping, while

| | 1860 Sq. Stat. Miles — Proportion to Whole | 1916 Sq. Stat. Miles — Proportion to Whole |
|---|---|---|
| Mapped from accurate topographical surveys based on triangulation or rigorous traverses | 1,957,755 = 0.0326 or roughly 1/30 | 8,897,238 = 0.1482 or roughly 1/7 |
| Mapped from less reliable surveys, chiefly non-topographical | 2,017,641 = 0.0336 or roughly 1/30 | 5,178,008 = 0.0866 or just over 1/12 |
| Mapped from route traverses and sketches | 25,024,360 = 0.4170 or roughly 2/5 | 37,550,552 = 0.6258 or little less than 2/3 |
| Entirely unsurveyed and unmapped | 30,997,054 = 0.5166 or just over 1/2 | 8,350,794 = 0.1391 or little less than 1/7 |

the parts that are now entirely unsurveyed and unmapped only amount to about one seventh instead of a little over one half, which was roughly the amount in 1860.

An estimate of the condition of the world's surveys as represented by the differently tinted areas on the maps for 1860 and 1916, taking the total area of the land-surface of the earth together with the unknown parts of the Arctic and Antarctic regions which may be either land or water, to be 60,000,000 square miles, gives in square miles the results shown on page 519.

## *SCIENTIFIC ITEMS*

We record with regret the death of Professor Charles Smith Prosser, head of the department of geology of the Ohio State University; of Dr. Joseph Hoeing Kastle, director of the experiment station of the University of Kentucky; of Dr. LeRoy Clark Cooley, emeritus professor of physics at Vassar College; of Professor Levi Leonard Conant, head of the department of mathematics at the Worcester Polytechnic Institute; of Sir T. Lauder Brunton, F.R.S., distinguished for his work in pharmacology; of Dr. V. von Czerny, professor of surgery at Heidelberg, and of Don José Echegaray, professor of mathematical physics at Madrid, distinguished also as a poet and dramatic author.

Sir Charles Parsons, the engineer, has been elected president of the British Association for the meeting to be held at Bournemouth in September next.

By vote of the board of trustees a bronze bust of Professor Thomas Chrowder Chamberlin will be placed immediately in Rosenwald Hall, University of Chicago, thus recognizing his long service to the university. Dr. Chamberlin has been professor and head of the department of geology since resigning the presidency of Wisconsin University in 1892.

Under the will of Eckley Brinton Coxe, Jr., late president of the University of Pennsylvania Museum, the university was bequeathed the sum of $500,000 as an endowment fund for the maintenance of the museum, its publications and expeditions. He also bequeathed the sum of $100,000 to the university, the income of which is to be used towards increasing the salaries of professors.

Seth Low, president of Columbia University from 1890 to 1901, and trustee from 1881 to 1914, by his will, bequeathed $15,000 to a cousin and $12,000 to the daughter of his former nurse, half of these sums to go to Columbia University on their deaths. On the death of Mrs Low several educational bequests became effective. Canton Christian College will receive about $70,000, the University of Virginia, Berea College and the Tuskegee Normal and Industrial Institute will each receive about $50,000. Mr. Low gave large gifts to Columbia University during his presidency, including the sum of $1,200,000 for the erection of the library building in memory of his father.